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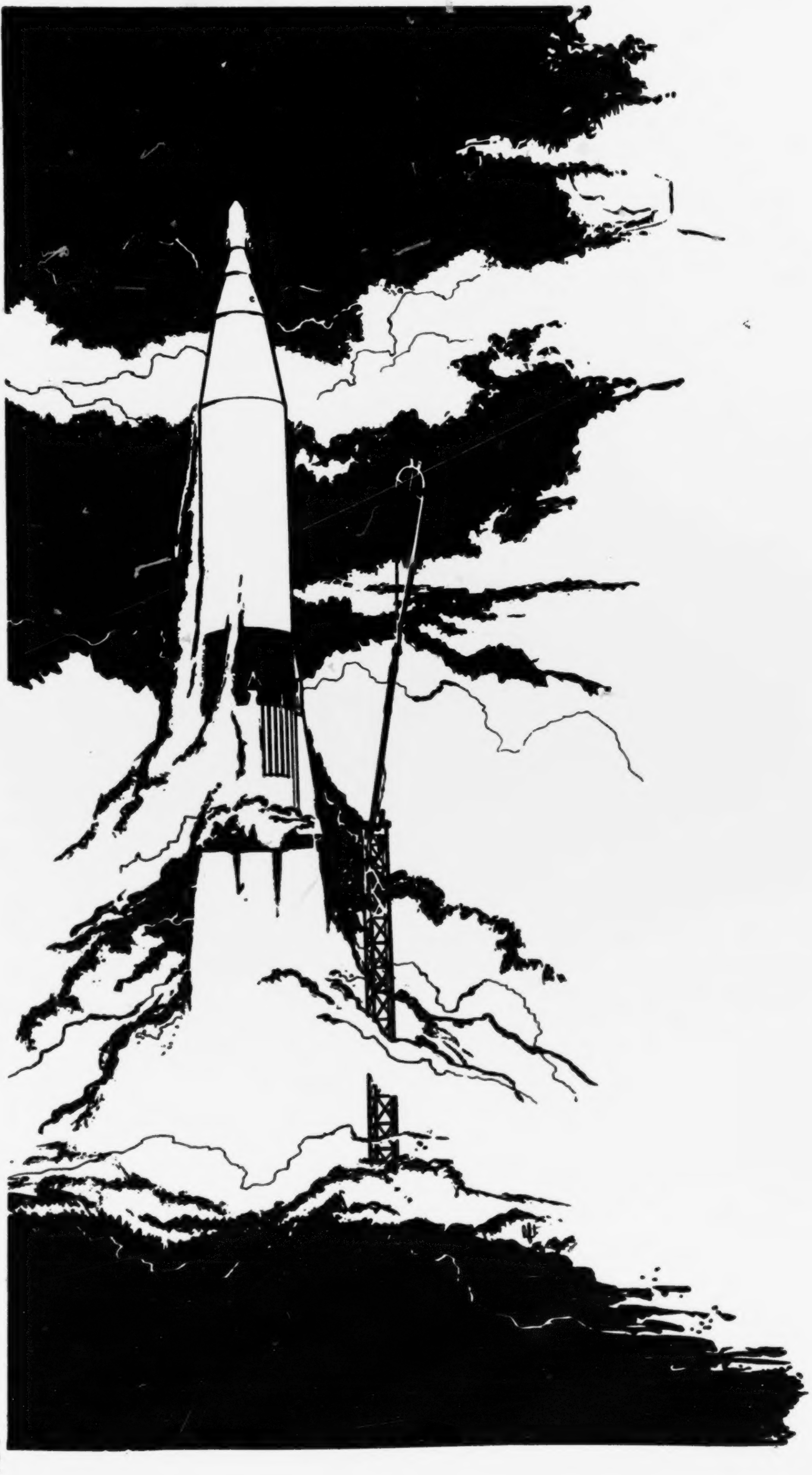
This combined text and study guide is for use by high school and junior college students enrolled in first year technical drawing courses and can also be used by the instructors in conjunction with any standard drawing test. It was developed by the author and tested in local classes before publication. The major sections are (1) Drafting Room Orientation, (2) Introduction to Drawing, (3) Multiview Sketching and Projection, (4) Working Drawing Interpretation, (5) Sections and Related Conventions, and (6) Isometric Drawings. Each of the 28 lessons includes objectives, references, textual material, and one or more assignments. Illustrations are line drawings and half tones. Supplementary material consist of 12 standard reference tables such as American Standard Association abbreviations, force and shrink fits, and thread standards. (EM)

ED 029 114

TECHNICAL DRAWING

AN APPLIED STUDY FIRST YEAR



STATE OF NEW JERSEY
DEPARTMENT OF EDUCATION
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TECHNICAL DRAWING

An Applied Study -- First Year

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Geographic Adaptability No limits
Uses of Material Students: high school and junior college
Users of Material Student manual

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PREFACE

This work is designed to be used both by the instructor as a course of study and by the student as an instructional work text.

The information contained in this work has been arranged in as logical a teaching order as possible and is designed for use at the FIRST-YEAR TECHNICAL level of drafting instruction.

This applied study has been designed in such a manner as to permit the instructor to use it with any standard drawing text that he prefers.

Related assignments with full drawing instructions have been included throughout the work. Questions related to instructional content have also been included with several of the lessons.

In addition to illustrations from other sources (see Bibliography), the author has included original illustrations at several points to provide supplementary instruction for specially related techniques. In particular, the author has included personal instructional methods for isometric drawing which have been proven successful in classroom instructional situations.

The author is indebted to Mr. Nathan Gifford, Superintendent of Schools, Morris Hills Regional District, and to the Board of Education for making available the opportunity to write this work.

I am particularly indebted and thankful to Mr. Earl Moran, Coordinator of the Vocational Department at Morris Hills, for his extensive advice and encouragement during the preparation of course content and for his personal efforts in arranging to have this work written.

Credit is also due to Mr. Benjamin Shapiro, Director of the Vocational-Technical Curriculum Laboratory, Rutgers the State University, for his advice and efforts toward the realization of the finished work.

Gratitude is expressed by the author to the State Department of Education, Vocational Division, for making this publication possible.

Special appreciation is extended to my wife, Ruth, for the many hours of dedicated labor so freely devoted to this work and also for her continuous encouragement which has contributed so much toward the completion of this work.

Thomas C. Mosley, Jr.

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UNIT I - DRAFTING ROOM ORIENTATION

Care of Equipment

Lesson 1

OBJECTIVES:

1. To understand the value of fine equipment.
2. To learn proper equipment storage and cleaning techniques.
3. To prevent vandalism.

REFERENCE:

1. Chapter 2, TECHNICAL DRAWING, by Giesecke, Mitchell, and Spencer; or any drafting text that describes in detail the correct methods of handling drafting equipment.

INFORMATION:

The drafting equipment in your possession will be of greater value in producing work of a high quality if it is kept in good condition by careful storage and proper cleaning. When equipment is used for its intended purpose, its "life" is increased,and greater efficiency in drafting will be experienced.

The following pages give an introduction to basic drawing equipment. Learn to appreciate the equipment at your disposal and the proper function of each item.

Techniques of drawing procedure applicable to the equipment will be learned in later lessons.

The Drawing Board

The drawing board is made of moderately soft wood and provides the backing for your drawing paper. Excessive drawing pressure may in time cause lines and grooves which will interfere with the production of quality work. You should learn to take care not to mar the surface by excessive pressure or other mistreatment. The board's surface should be kept clean and may require, with the instructor's approval, light sanding to maintain a usable surface. The best preventive maintenance, however, is to work neatly and carefully.

The Drawing Table

Each work table is designed to be used by several students. The drawing board should be used on top of the table, and incomplete work remains attached to the board. No work should be attached directly to the top of the work table.

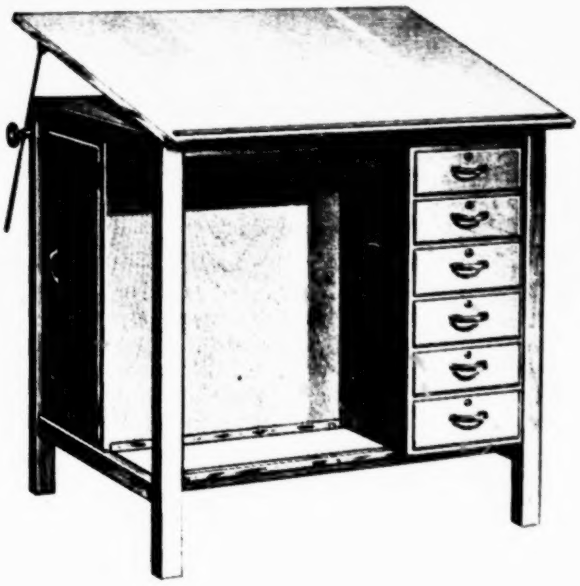


Figure 1. Typical Work Station

Occasional wiping with a damp cloth will keep the top clean. Always use care not to mar the top by sliding or dropping the drawing board on the table.

The T-Square

The T-square is composed of two parts, the head and the blade. The two parts are firmly attached at right angles. Care must be taken not to abuse the T-square and cause the head to loosen.

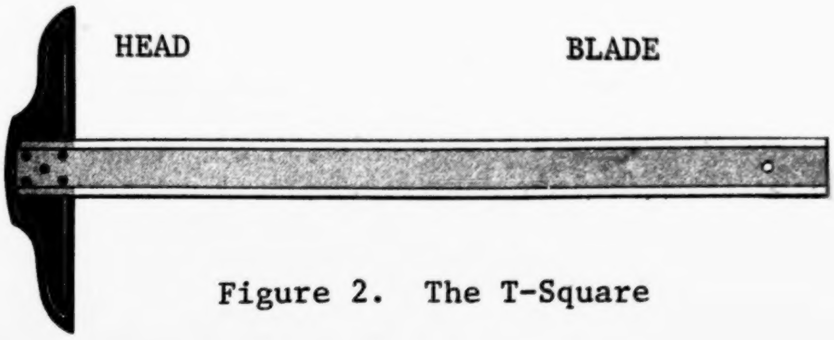


Figure 2. The T-Square

The upper edge of the blade and the inner edge of the head are the "working edges" and must be kept free of nicks if the T-square is to sit accurately against the edge of the drawing board.

Most T-squares are made of hardwood. Some have plastic edges providing visibility of work along the blade. The instrument is cleaned by wiping with a damp cloth. Excessive use of water or detergents in cleaning will cause damage to the finish and possible warping of the wood parts.

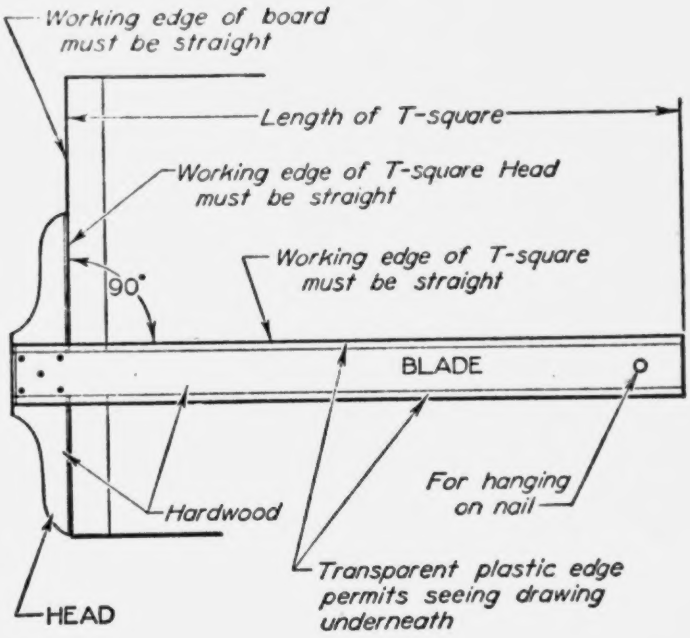

Working edge of board must be straight
Length of T-square
Working edge of T-square Head must be straight
90°
Working edge of T-square must be straight
BLADE
For hanging on nail
Hardwood
Transparent plastic edge permits seeing drawing underneath
HEAD

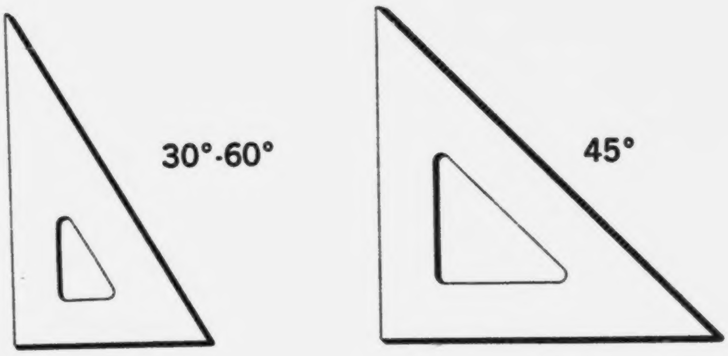
Figure 3. Placing the T-Square

T-squares should be stored placing the head into the compartment first to protect it from being damaged by contact with other equipment.

Triangles

Drafting triangles are generally made of transparent sheet plastic to provide visibility of work while drawing. Two basic types of triangles are generally used by the draftsman. Each triangle provides a 90° angle for the drawing of vertical lines and two 45° angles or a 30° angle and a 60° angle which are the most commonly required angles in drafting.

Figure 4. Triangles



These instruments must be stored flat in the equipment drawer to prevent warping and must not be dropped, as they can be broken quite easily.

Again, as with other equipment, cleaning should be done using a damp cloth, and only mild soap is required. Excessive use of detergents will scratch the surfaces, and transparency will be affected.

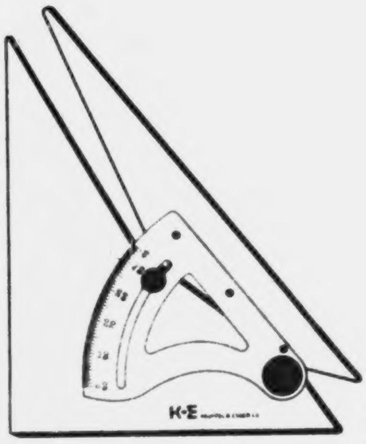


Figure 5. Adjustable Triangle

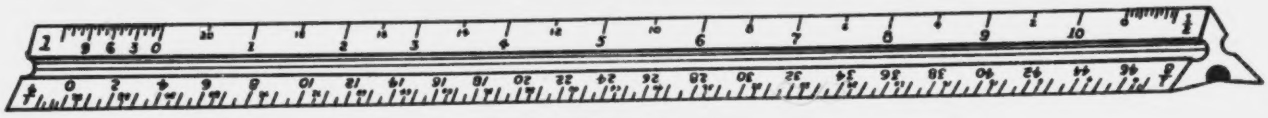
Adjustable Triangle

In certain drafting situations representative angles may be required which cannot be directly composed by separate or combined use of the 45° or 30°-60° triangles. In these cases, an adjustable triangle is used to directly "set" the required angle, eliminating the necessity of tilting the T-square or holding the other triangles in an off-set position.

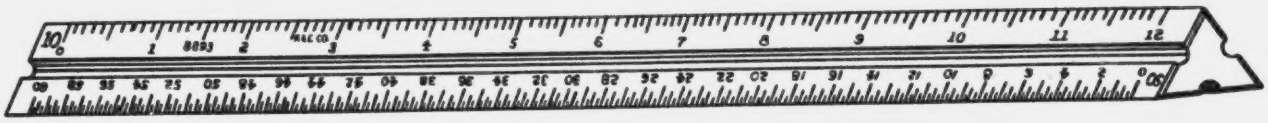
Care in storage and handling is required as with the other triangles.

Scale

The most commonly used hardwood scales are the architect's scale and the engineer's scale. The scale is used to enlarge or decrease drawings to a convenient size by measuring on a particular "scale." The ratio of reduction between the size of the part to be drawn and the size of the paper is usually the primary concern. More will be said concerning the use of the scale in a later lesson.



Architects Scale



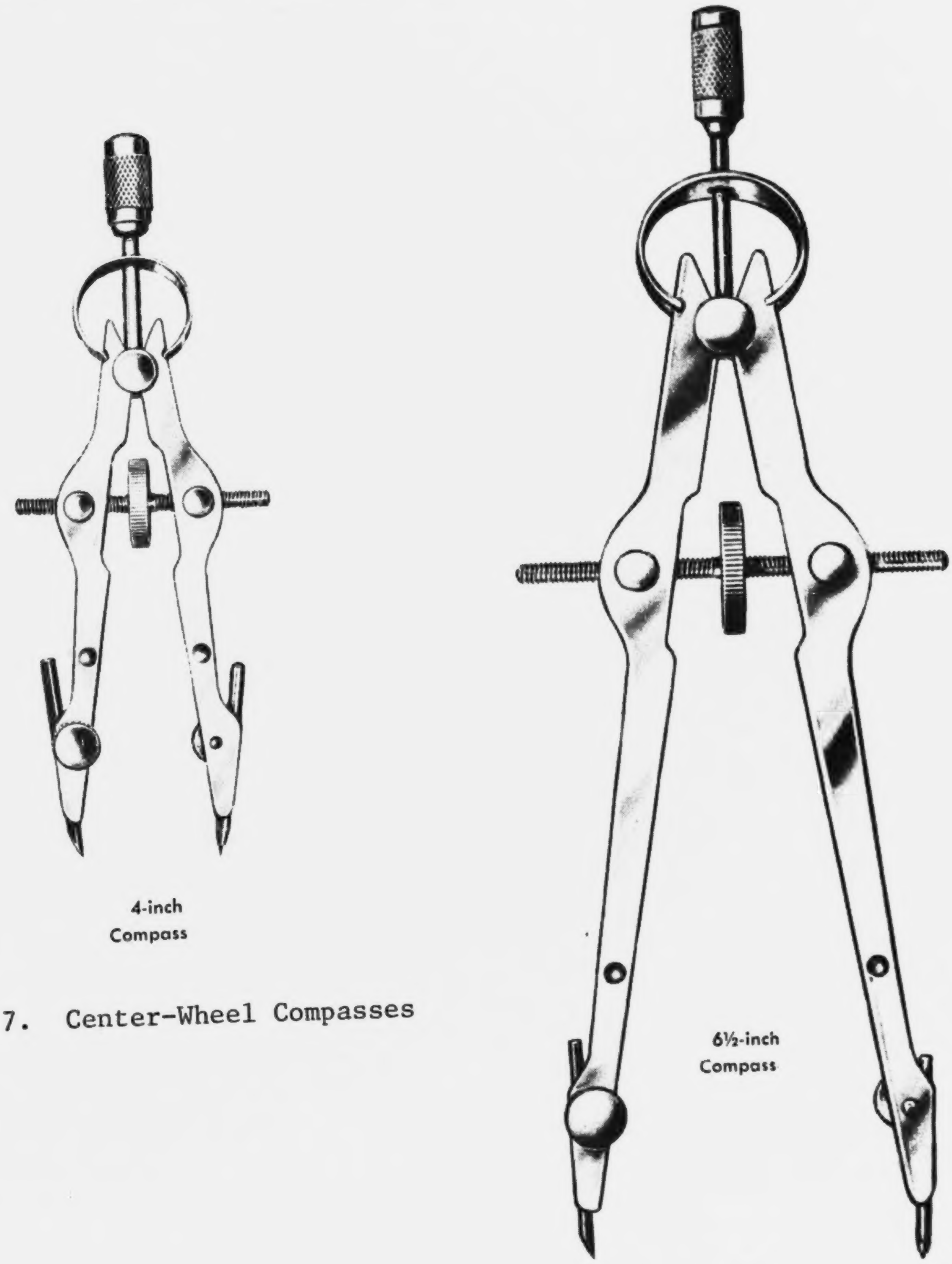
Engineers Scale

Figure 6. Triangular Drafting Scales

The calibrations on the scale are merely printed and will wear off if detergents are used in cleaning. A damp cloth only should be used for cleaning the scale. The scale should be handled and stored carefully to prevent nicking the edges. A damaged scale is useless for accurate measurements or drawings.

Drafting Compasses

Drafting compasses of many designs and sizes are available to the draftsman. For stability in maintaining an accurate setting, the center-wheel design is recommended for use by the student.


4-inch Compass

6½-inch Compass

Figure 7. Center-Wheel Compasses

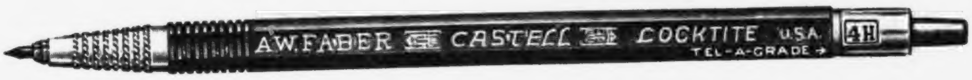
The compass is probably the most sensitive instrument in your possession and should be handled with extreme care. Under no circumstances should you open the compass beyond its intended limits or attempt to disassemble the instrument. Either of these abuses will either greatly reduce the life of the instrument or destroy it completely. Always store the compasses in their containers to protect them from damage.

Two sizes of compasses should be available to the students for use with various work size requirements. Check the compass with each use to see that all parts are stable and secure to maintain accuracy.

Mechanical Lead Holders

A mechanical lead holder is basically a pencil. The difference is that only the lead becomes shorter with use and is replaced when necessary. The lead holder is more convenient to use, since it remains the same length. Varying hardness of lead may be obtained by the removal of one piece and the inserting of another.

CASTELL LOCKTITE


A.W.FABER CASTELL LOCKTITE U.S.A.
TEL-A-GRADE
4H

MARS LUMOGRAPH

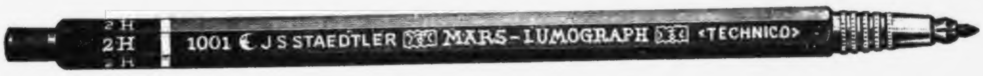

2H
1001 J S STAEDTLER MARS-LUMOGRAPH <TECHNICO>

Figure 8. Mechanical Lead Holders

The lead is secured in the holder by means of a chuck. By loosening the chuck you may slide the lead forward in the holder for sharpening and proper adjustment.

This instrument is delicate and should receive gentle handling. Dropping the holder will break the lead or the holder, reducing the useful life of both.

Pencils and Lead

Some draftsmen prefer to use regular wooden pencils and select the desired hardness of lead by having several pencils available. This necessitates the sharpening of pencils by mechanical means and in many drafting rooms is inconvenient.

MARS LUMOGRAPH

H
2886 J S STAEDTLER, INC MARS LUMOGRAPH GERMANY

VENUS

AMERICAN PENCIL CO. NEW YORK - VENUS - DRAWING - 3H

Figure 9.
Drawing Pencils

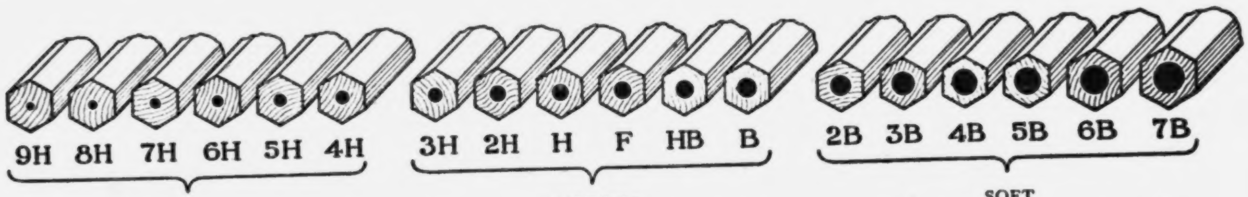
KOH-I-NOOR

MADE IN U.S.A. L.&C.HARDTMUTH, INC "KOH-I-NOOR" × 1500 × HB ×

CASTELL

A.W.FABER "CASTELL" * 3H *

When using either the mechanical lead holder or drafting pencils, selection of the proper grade of lead is important to good drawing. The character of line produced by the varying grades of lead is soon learned by the student, and the choice of lead for various purposes becomes relatively easy.



HARD
The harder pencils in this group (left) are used where extreme accuracy is required, as on graphical computations and charts and diagrams. The softer pencils in this group (right) are used by some for line work on engineering drawings, but their use is restricted because the lines are apt to be too light.

MEDIUM
These grades are for general-purpose work in technical drawing. The softer grades (right) are used for technical sketching, for lettering, arrowheads, and other freehand work on mechanical drawings. The harder pencils (left) are used for line work on machine drawings and architectural drawings. The H and 2H pencils are widely used on pencil tracings for blueprinting.

SOFT
These pencils are too soft to be useful in mechanical drafting. Their use for such work results in smudged, rough lines which are hard to erase, and the pencil must be sharpened continually. These grades are used for art work of various kinds, and for full-size details in architectural drawing.

Figure 10. Pencil Grade Chart

It is recommended that a medium grade of lead be used by beginning students. The selection of other grades of lead should be made only after considerable practice in drawing in order to gain the "feel" of the lead in the production of your own work.

Erasing Shield

The erasing shield is a thin slotted metal plate used to protect surrounding drawing areas when correcting local errors on drawings. The use of this shield will eliminate repeated drawing of detail which might otherwise be erased.

The erasing shield is not useful if it is bent or warped. It should be kept clean to prevent smudges on drawings.

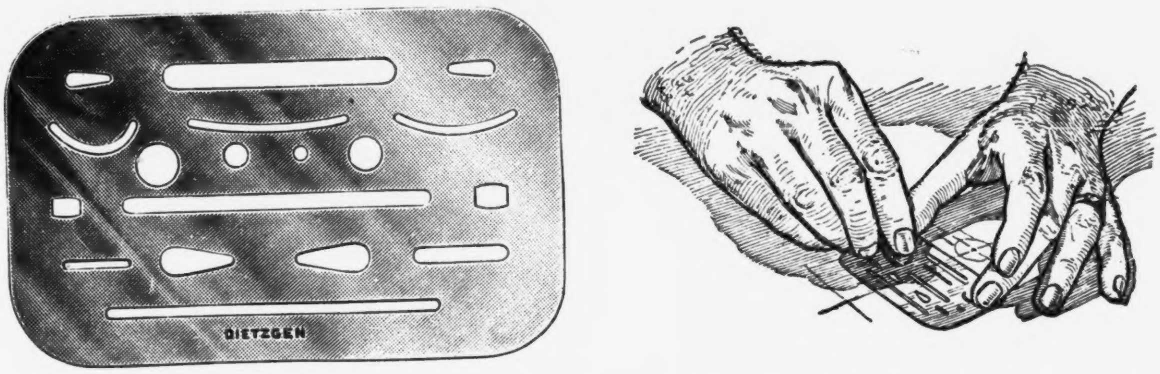
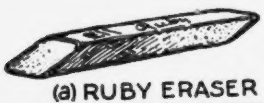


Figure 11. Erasing Shield and Its Use

Erasers

As a general rule, soft pliable pencil erasers are preferred by draftsmen to erase light lines during the construction stage of drawing. Best results are obtained when a hard surface, such as a triangle placed under the paper, backs the drawing while erasing. Cleaning erasers are used for large areas and should never be used as a substitute for the regular pencil eraser.


(a) RUBY ERASER
FOR GENERAL USE-PENCIL & INK

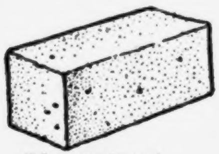

(b) ARTGUM
FOR CLEANING PURPOSES ONLY

Figure 12. Erasers

Other pieces of drawing equipment are also useful to the draftsman, and preferences may be formed after practice and some degree of skill is gained. Some investigation is recommended to learn the availability of other types of equipment.

Remember that the work produced will be no better than the equipment used or the skill with which it is handled.

ASSIGNMENT:

Study the equipment issued to you.

1. Observe the condition of each piece of equipment. Be sure your equipment is in good repair and is cleaned and ready for use.

2. What grade of lead is in your mechanical lead holder? What is the next softer grade?

3. Locate and check the working edges of your T-square and board.

4. How should you clean wooden drawing instruments?

UNIT I - DRAFTING ROOM ORIENTATION

Conforming to Authority

Lesson 2

OBJECTIVES:

1. To establish teacher-student relationship.
2. To recognize the value of training.

REFERENCES:

1. Industrial magazines.
2. Newspaper employment ads.

INFORMATION:

The school drafting room environment is similar to the industrail drafting room, not only in physical structure but in other ways. The chain of command is structured similarly to industry. In industry the master draftsman holds authority over the personnel under him and is the one who checks the quality and content of work produced. In the school the teacher is the master draftsman and supervises the students and works with them to see that the best possible product is produced.

The teacher holds the position of authority due to his specialized training and technical knowledge. You must understand that the instructions given by the teacher have a purpose and are not designed merely to harass you.

The student is in the position of seeking knowledge and must bear this fact in mind when confronted by the instructor. Personality differences may exist as in any social situation. However, adjustments can be made, usually by the younger person, since he is learning to work with others.

The student who puts forth the most effort will undoubtedly gain the most from any instruction. If effort is put forth in the school drafting room, the student will be better prepared to find his preferred employment in a related area. Training need not stop at the secondary level, but may continue throughout the years of employment. Should the situation be that drafting is not the student's primary concern, he will find that the work habits developed will be useful in any working position and will improve the student's ability to see any problem through to a successful end.

Figure 1. Drafting Instructor lectures on engineering drawings in drafting section to trainees.

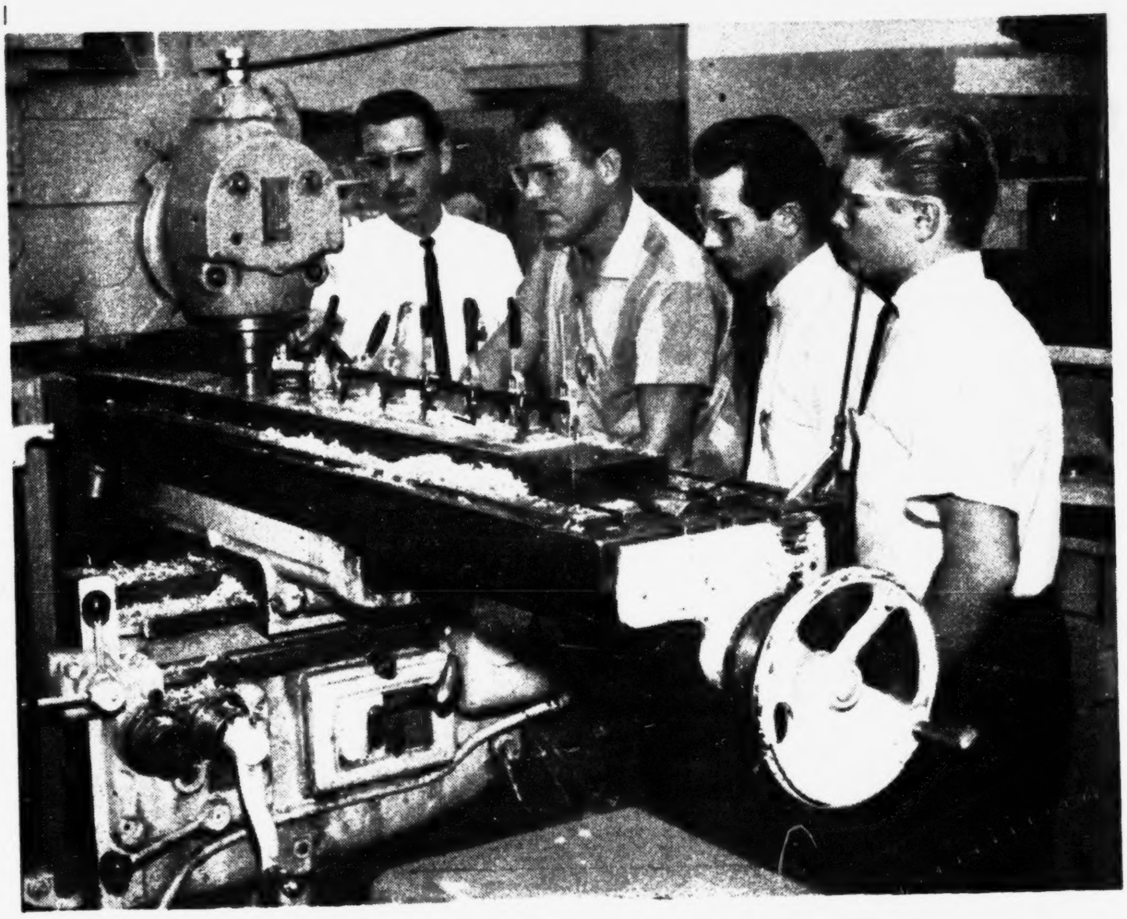


Figure 2. Instructor takes trainees to machine shop for indoctrination in manufacturing processes, explaining machining operations.

Throughout life you will find many situations where conforming to authority is necessary. Usually, you stand to gain much from individuals you will meet and work with. If you realize the potential value of what can be learned by working with other people, you as the learner will come out ahead.

Your training in drafting is not only valuable toward future employment possibilities, but also in understanding the materials and products surrounding you in everyday life. When you are confronted by plans or blueprints, you will be in a position to determine for yourself the soundness of structure and design in the products you purchase. You might say, then, that your training in drafting can be of economic value as well.

Figure 3. Cooperation between industrial personnel provides a continual interchange of ideas.

You, as the student, must determine the values placed upon your study of drafting. These values will be directly demonstrated by how well you work with others, especially with those from whom you can learn and also through the degree of effort you put forth.

QUESTIONS:

1. What types of jobs are available today which are related to drafting?
2. How is the teacher similar to the boss in industry?
3. Why is it wiser to consult the teacher about a problem rather than the person next to you?
4. Do you feel that you will gain more from this course if you place more effort into it? If so, why?

UNIT I - DRAFTING ROOM ORIENTATION

Subject Orientation   Lesson 3

OBJECTIVES:

1. To provide a brief history of mechanical drawing.
2. To introduce the "vocabulary" of the graphic language of drafting.
3. To introduce "projection" of views.

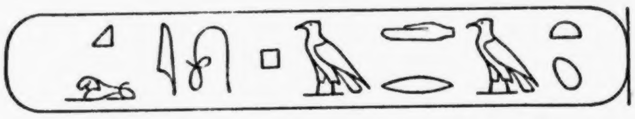
REFERENCES:

1. Chapter 1, TECHNICAL DRAWING, Giesecke, Mitchell, and Spencer.
2. Chapter 1, MECHANICAL DRAWING, French and Svensen.

INFORMATION:

Communication between people of various lands is limited by the language barrier. Through lack of communication, understanding of ideas, objectives, and dreams become limited, and progress toward mutual goals is slowed or completely stopped in many areas.

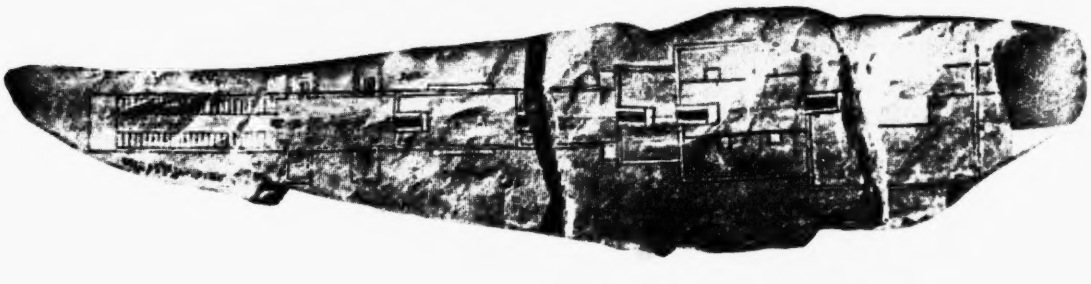
A world language of words and sentences still does not exist today and will probably be a long time in the making. There is, however, a common denominator in communications, the GRAPHIC LANGUAGE.

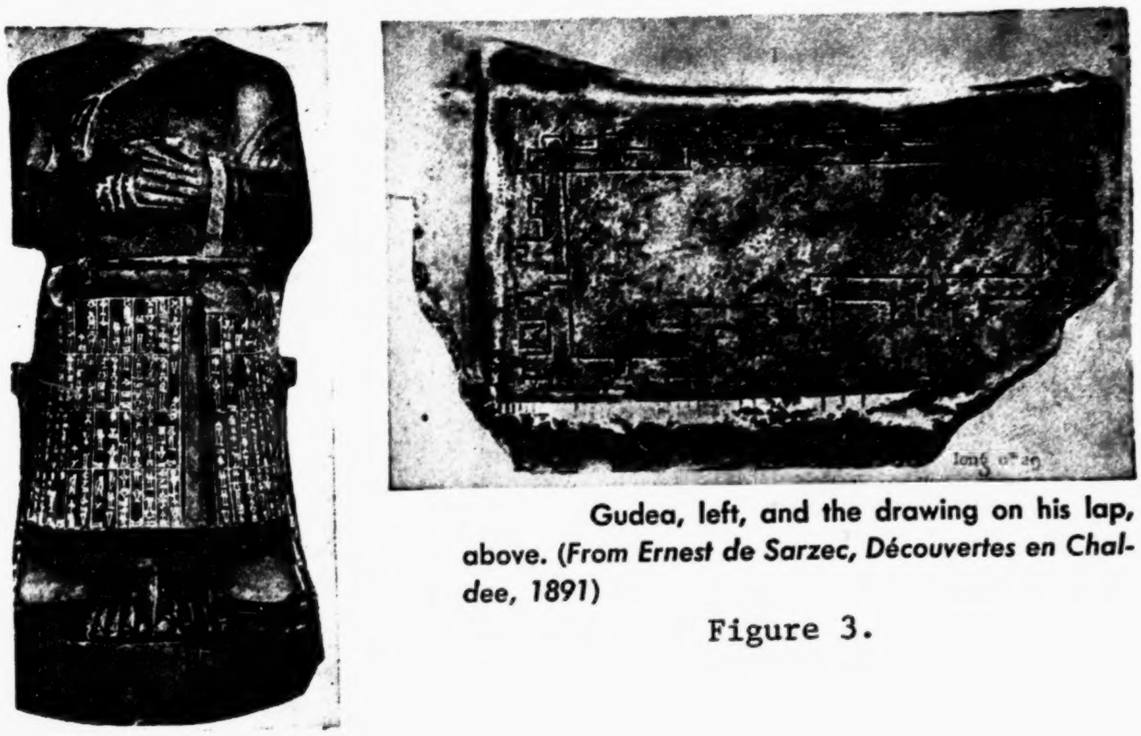


Egyptian Hieroglyphics.

Figure 1. One of the earliest "graphic languages".

Figure 2. **Below, the plan on limestone of the tomb of an Egyptian king. (*From Clark and Engelbach, Ancient Egyptian Masonry*)**





Gudea, left, and the drawing on his lap, above. (*From Ernest de Sarzec, Découvertes en Chaldee, 1891*)

Figure 3.

A language of pictures placed on the page in a universally understood system provides an understanding of even the most complicated structures and machines. Drafting standards established over the years have resulted in the production of a truly UNIVERSAL LANGUAGE.

Throughout the ages, drawings have been used by thousands of individuals to communicate ideas despite the barrier of written words.

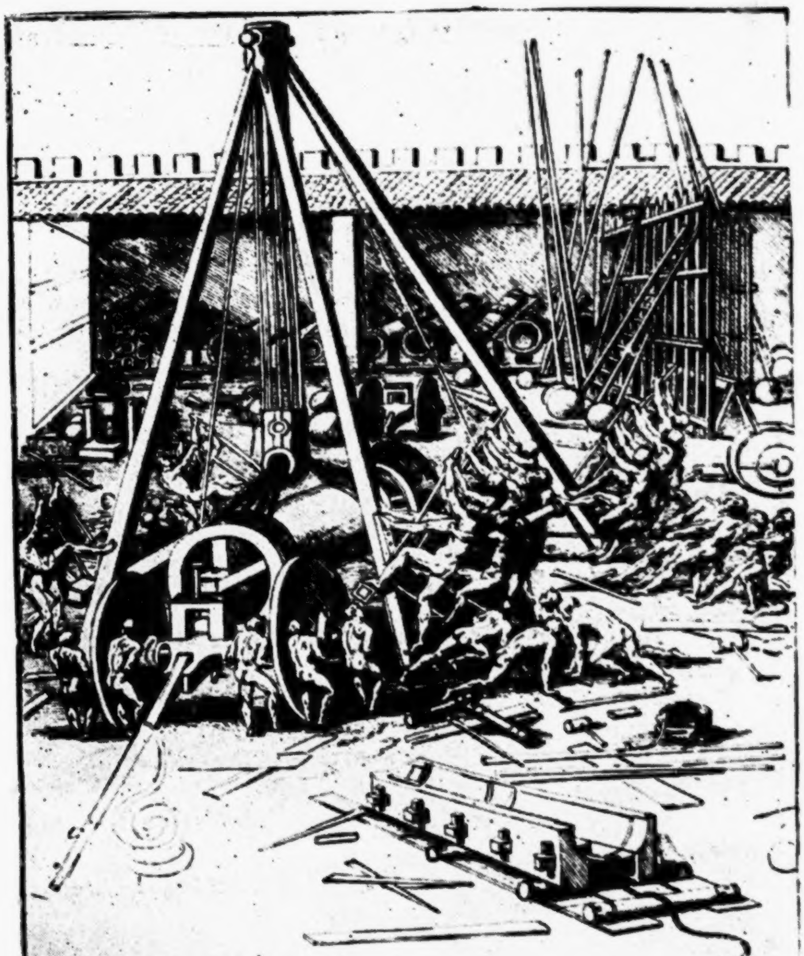


Figure 4.

An Arsenal, by Leonardo da Vinci.

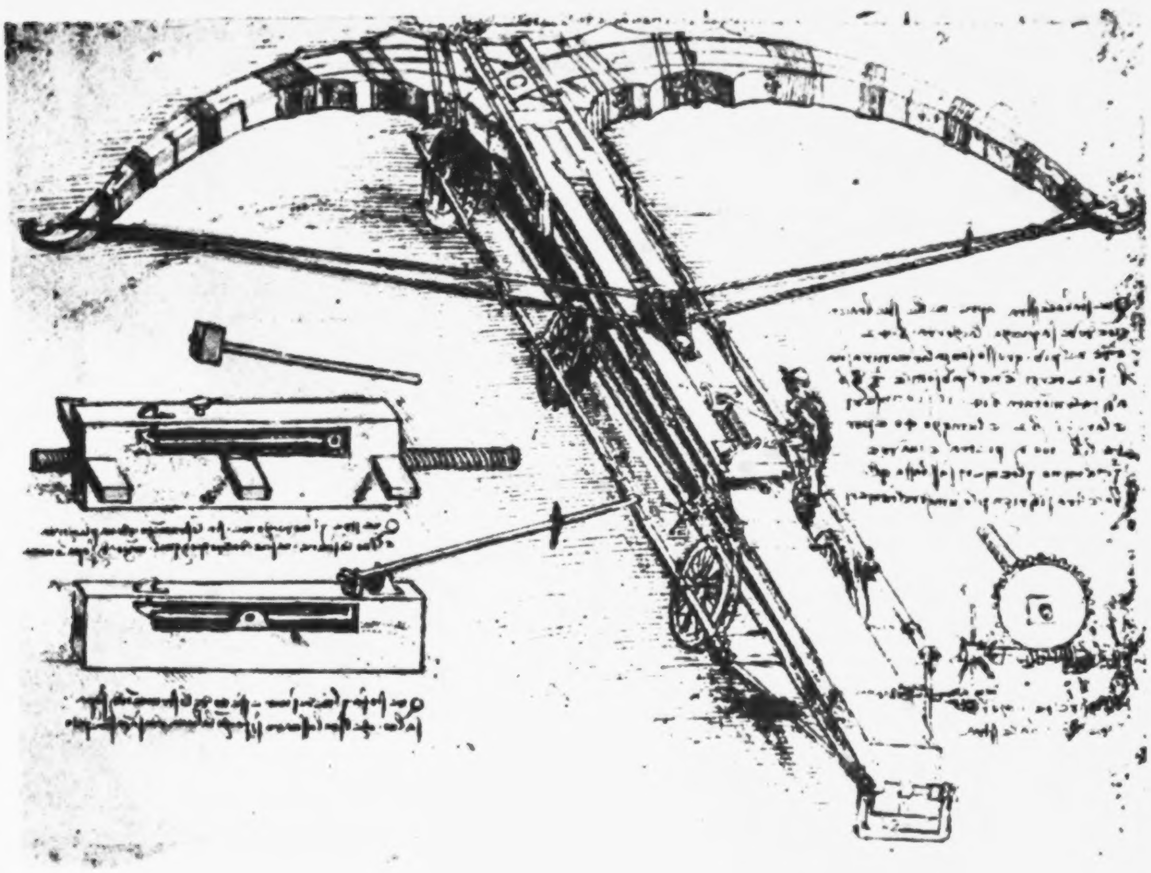


Figure 5.

Leonardo da Vinci's sketch of a giant crossbow. Notice the two suggestions showing the tripping action of the crossbow. Da Vinci often wrote his comments from right to left as a mirror image of ordinary writing. In this way he kept many of his ideas as private as possible. *(Courtesy Lieb Museum)*

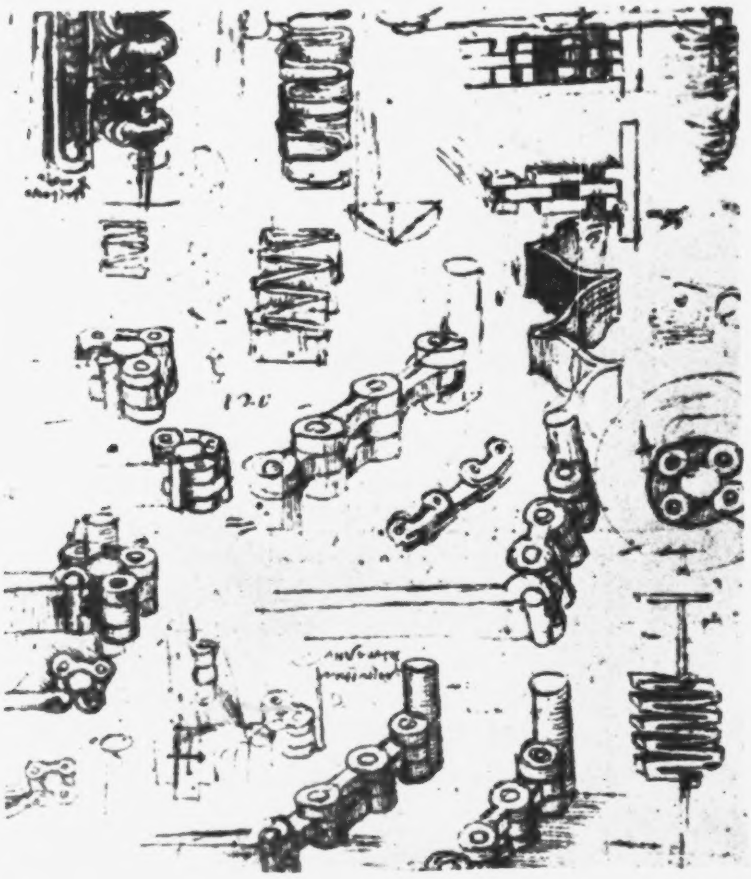
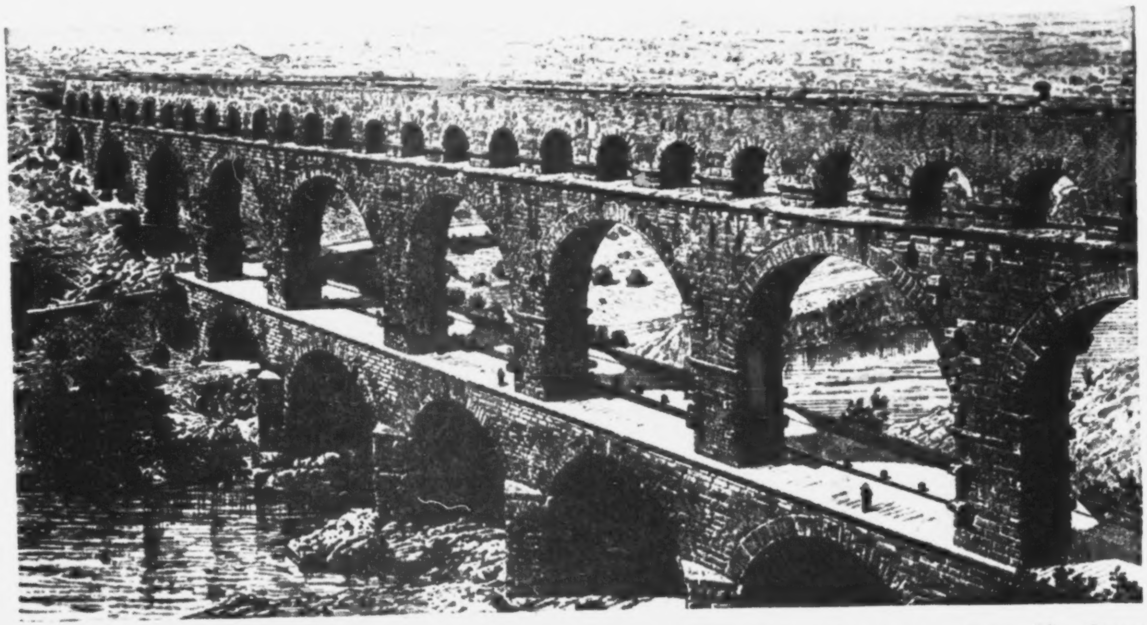


Figure 6.

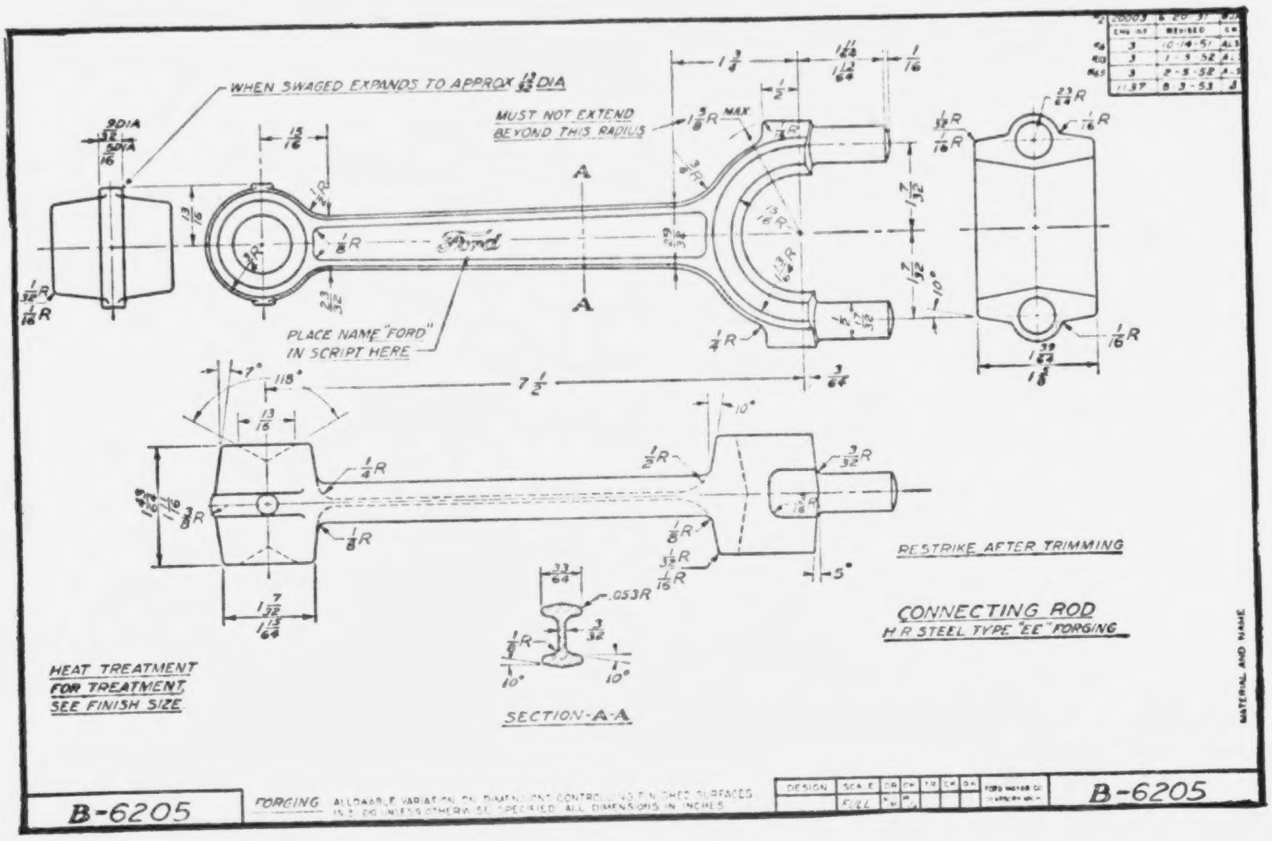
Right, Leonardo da Vinci's sketch of a sprocket chain. Notice the many different views. *(Courtesy Lieb Museum)*

Today, industry has turned from the old ARTISTIC form of graphic description and is using the TECHNICAL approach to provide the accuracy necessary in the description of the product to the person needing it.



Engineers of ancient Rome knew the importance of making drawings. The Pont du Gard, near Nîmes, France, is a good example of the aqueducts they built.

Figure 7. Early "artistic" form of graphic representation.


WHEN SWAGED EXPANDS TO APPROX 13/32 DIA
MUST NOT EXTEND BEYOND THIS RADIUS
PLACE NAME "FORD" IN SCRIPT HERE
Ford
A
A
RESTRIKE AFTER TRIMMING
CONNECTING ROD
H R STEEL TYPE "EE" FORGING
HEAT TREATMENT FOR TREATMENT SEE FINISH SIZE
SECTION-A-A
.053R
7 1/2
118°
7°
10°
5°
FORGING
MATERIAL AND NAME
DESIGN
SCALE
FULL
B-6205
B-6205

Forging Drawing of Connecting Rod.

Figure 8. Modern "technical" approach to the graphic language.

It is the job of the draftsman to understand the language of drafting thoroughly in order to use the "descriptive geometry", the "grammar", and the "penmanship" of his field in a "professionally literate" manner. Through the use of drawing instruments and drafting standards* which have helped to give industry and the engineering fields a uniform and effective language, blueprints made by any trained individual can be universally understood by other persons having a knowledge of drafting.

As we speak of the "grammar" of the language, reference is made to the fundamental principles of correct graphic representation or the manner in which the views of an object are projected on the page or "blueprint". The skill with which the work is executed becomes the "penmanship" of the language.

As a student in drafting, the meaning of neatness, speed, and accuracy will become apparent to you. Once the basic skills have been learned and the habit of being neat is instilled, accuracy and speed will follow. Speed should not be your primary concern but should be developed as the skills of drafting are mastered.

In order to be successful as a draftsman, you must develop the ability to "think in three dimensions." This ability will lead to "constructive imagination", one of the principal values to be obtained from a study of the graphic language. The ability to visualize objects from various positions with a continued reference to all three dimensions is of primary importance to good drafting techniques.

We spoke earlier of "projecting" a view of an object onto the page. This process of projecting an image begins with the observer's eye or "station point" in reference to the "object" being drawn. An imaginary "plane of projection" is then developed giving us the view of the object which will appear in the drawing. The "projectors" are the lines which frame the views on the page and become guides from which other views of the object may be projected.

There are many types of projection used in mechanical drawing including parallel and perspective which are the starting points or the origin of the many other methods of projection. Throughout this course you will learn applications of the basic principle of "projection of views" which forms the "backbone" of good drafting techniques.

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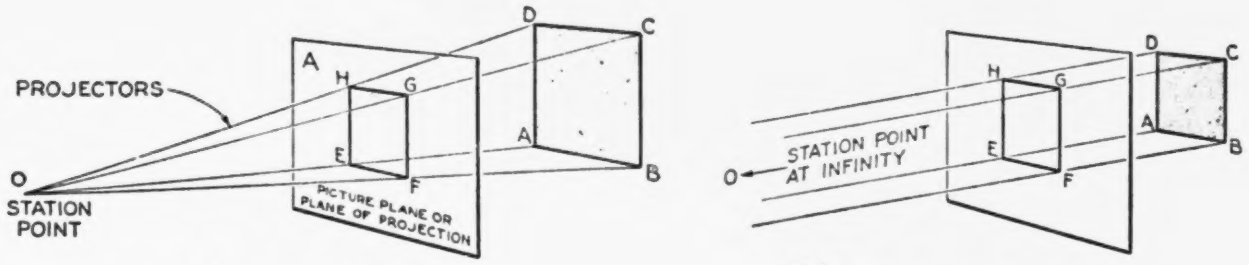
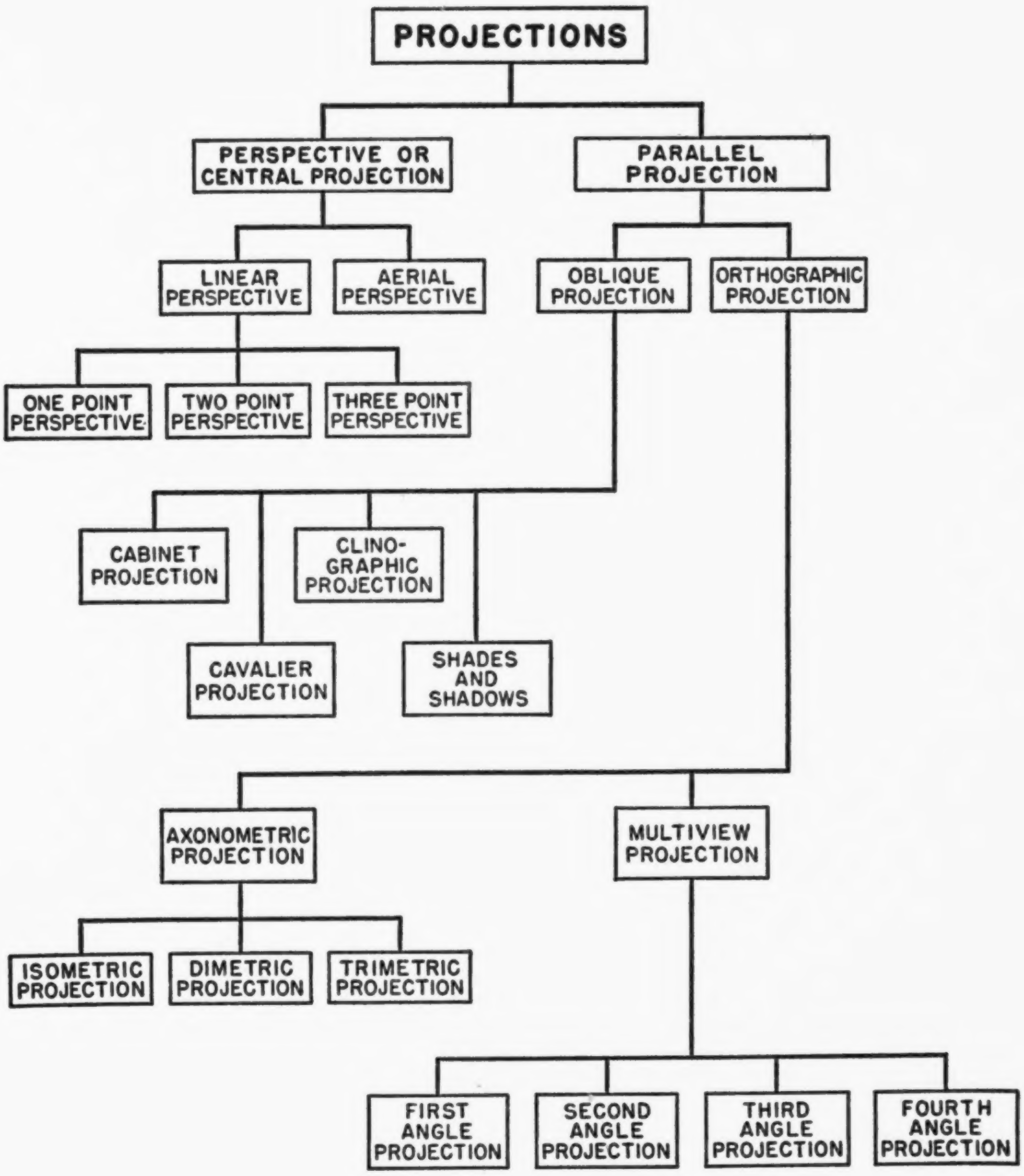
* American Standards Association with the American Society for Engineering Education and the American Society of Mechanical Engineers as sponsors has prepared and published the AMERICAN DRAFTING STANDARDS MANUAL, ASA Y-14 in seventeen separate sections. These publications are now in the process of development and will be published as approved standards as soon as they are completed.


PROJECTORS
O
STATION POINT
A
H
G
E
F
D
C
B
PICTURE PLANE OR PLANE OF PROJECTION
STATION POINT AT INFINITY

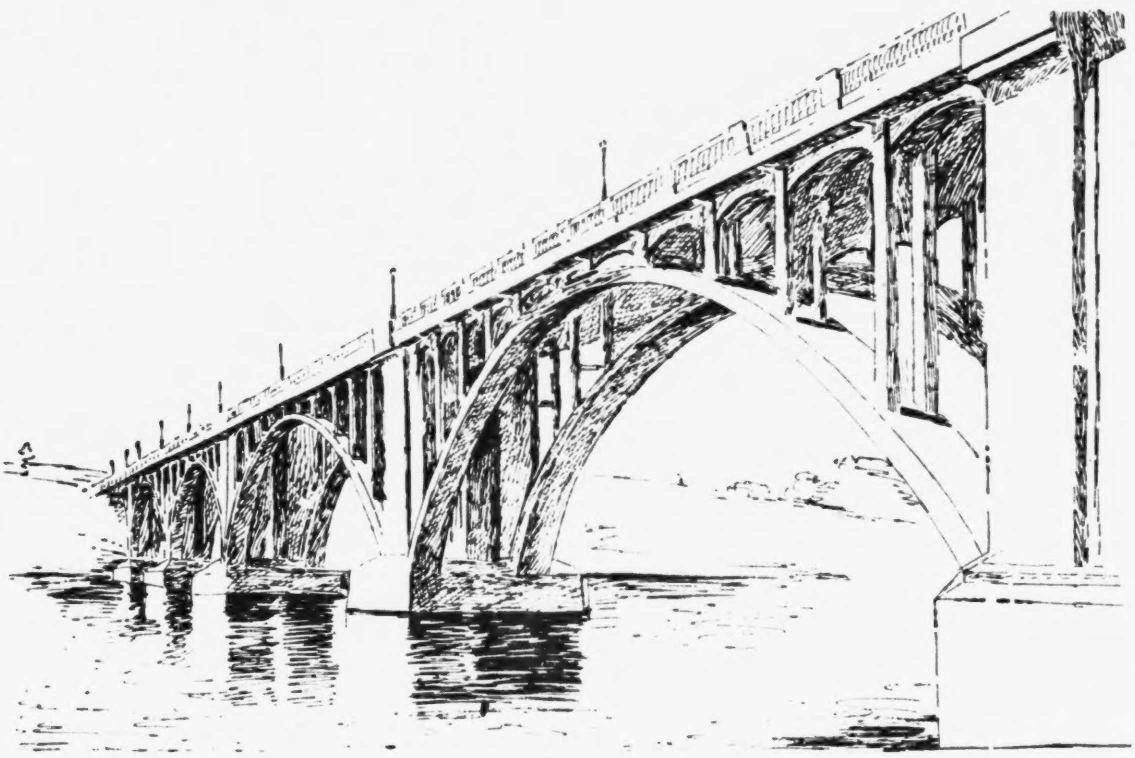
(a) PERSPECTIVE (b) PARALLEL PROJECTION

Figure 9.


PROJECTIONS
PERSPECTIVE OR CENTRAL PROJECTION
PARALLEL PROJECTION
LINEAR PERSPECTIVE
AERIAL PERSPECTIVE
OBLIQUE PROJECTION
ORTHOGRAPHIC PROJECTION
ONE POINT PERSPECTIVE
TWO POINT PERSPECTIVE
THREE POINT PERSPECTIVE
CABINET PROJECTION
CLINOGRAPHIC PROJECTION
CAVALIER PROJECTION
SHADES AND SHADOWS
AXONOMETRIC PROJECTION
MULTIVIEW PROJECTION
ISOMETRIC PROJECTION
DIMETRIC PROJECTION
TRIMETRIC PROJECTION
FIRST ANGLE PROJECTION
SECOND ANGLE PROJECTION
THIRD ANGLE PROJECTION
FOURTH ANGLE PROJECTION

Classification of Projections.

Figure 10.



A perspective drawing of a bridge. Notice how it gives the effect of distance.

Figure 11.

Students' use of texts and other reference materials in addition to classroom instruction will be an invaluable aid in providing a depth of understanding not possible within the limits of classroom instruction time. It is recommended that the student realize the limitation of his understanding and seek to develop his understanding through the use of reference materials and through talking with persons having a knowledge of drafting. Make an effort to seek knowledge, and you will not fail to find it.

QUESTIONS:

1. How long would you estimate that the graphic language has existed?
2. Why are blueprints important today?
3. List reference materials related to drafting which are available in the classroom.
4. Where would you look in a school or public library to seek additional information on drafting?
5. Why do we refer to mechanical drawing as a "universal language"?

Equipment Handling Techniques

Lesson 1

OBJECTIVES:

1. To learn the placement of equipment for use.
2. To learn equipment handling techniques which develop neat drawing abilities.
3. To learn how to properly use the drawing pencil.

REFERENCES:

1. Chapter 2, TECHNICAL DRAWING, Giesecke, Mitchell, and Spencer.
2. Chapter 2, MECHANICAL DRAWING, French & Svensen.

INFORMATION:

Take time from the beginning of your drafting instruction to learn the correct procedures for handling drafting equipment. The basic techniques of drawing will greatly increase the degree of success you will have during each phase of your training.

Table and Board

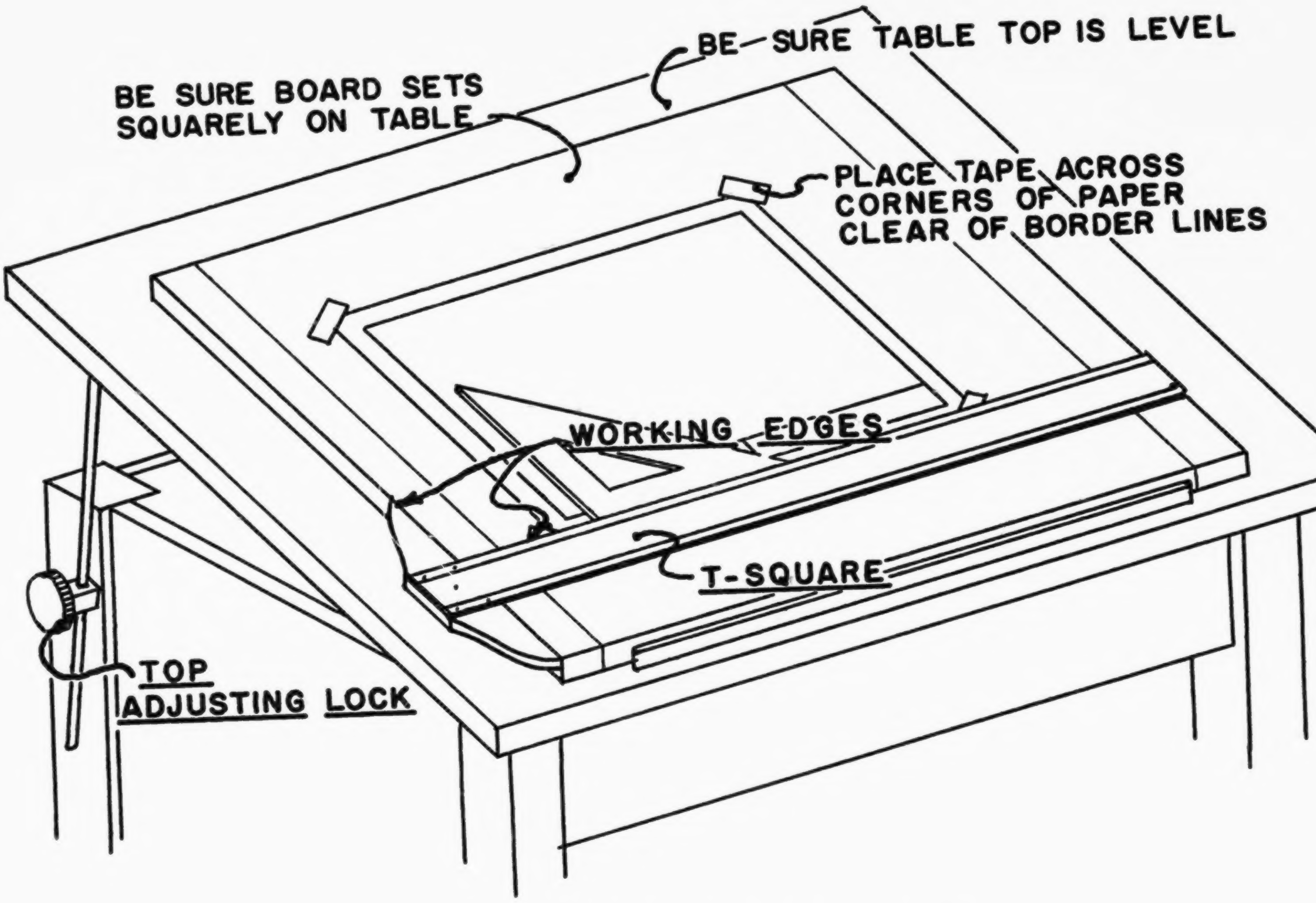
The drawing board becomes the mounting place for all drawing work in progress. Care should be taken in placing the board squarely on the table, being sure that the table top is level and locked securely. If the table top is not secure, damage to the top or the instruments may result, should the top fall. The table top should not be moved from its pre-adjusted position which is raised approximately five inches at the rear edge.

The drawing board should be steady in its position. The board will "rock" if the table top is not level.

T-Square and Triangles

The T-square is placed against the working edge of the board with the head placed opposite the hand used for drawing. This permits free movement of the T-square over the drawing area without interfering with drawing motions. It is important to keep the "head" tightly positioned against the board to keep all lines drawn on the page parallel to one another. The T-square is always placed horizontally on the board and is never used in the vertical position.

The triangles are generally used against the top edge of the T-square blade and only in special instances are they used independent of the T-square. It is of utmost importance to secure the T-square and triangles with the free hand when drawing.


BE SURE TABLE TOP IS LEVEL
BE SURE BOARD SETS SQUARELY ON TABLE
PLACE TAPE ACROSS CORNERS OF PAPER CLEAR OF BORDER LINES
WORKING EDGES
T-SQUARE
TOP ADJUSTING LOCK

PLACING EQUIPMENT FOR USE

Figure 1.

Placement of Paper

The drawing paper, a special bond designed for drawing, is first aligned with the top edge of the T-square blade and positioned and secured with the free hand by taping at the upper corners. Then smooth the paper downward and secure the lower corners. The tape should be placed diagonally across the corners taking care not to interfere with the area of the page where borderlines will occur. When removing the tape, pull upward slowly in order not to lift the surface of the paper with the tape.

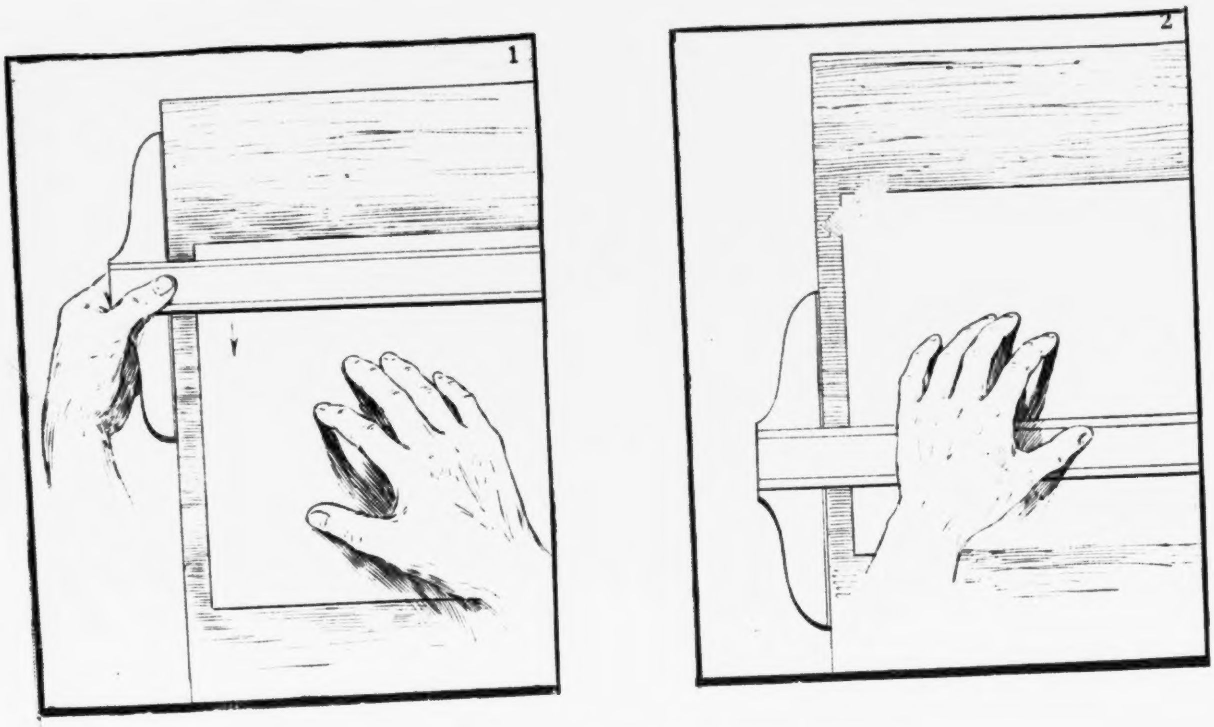
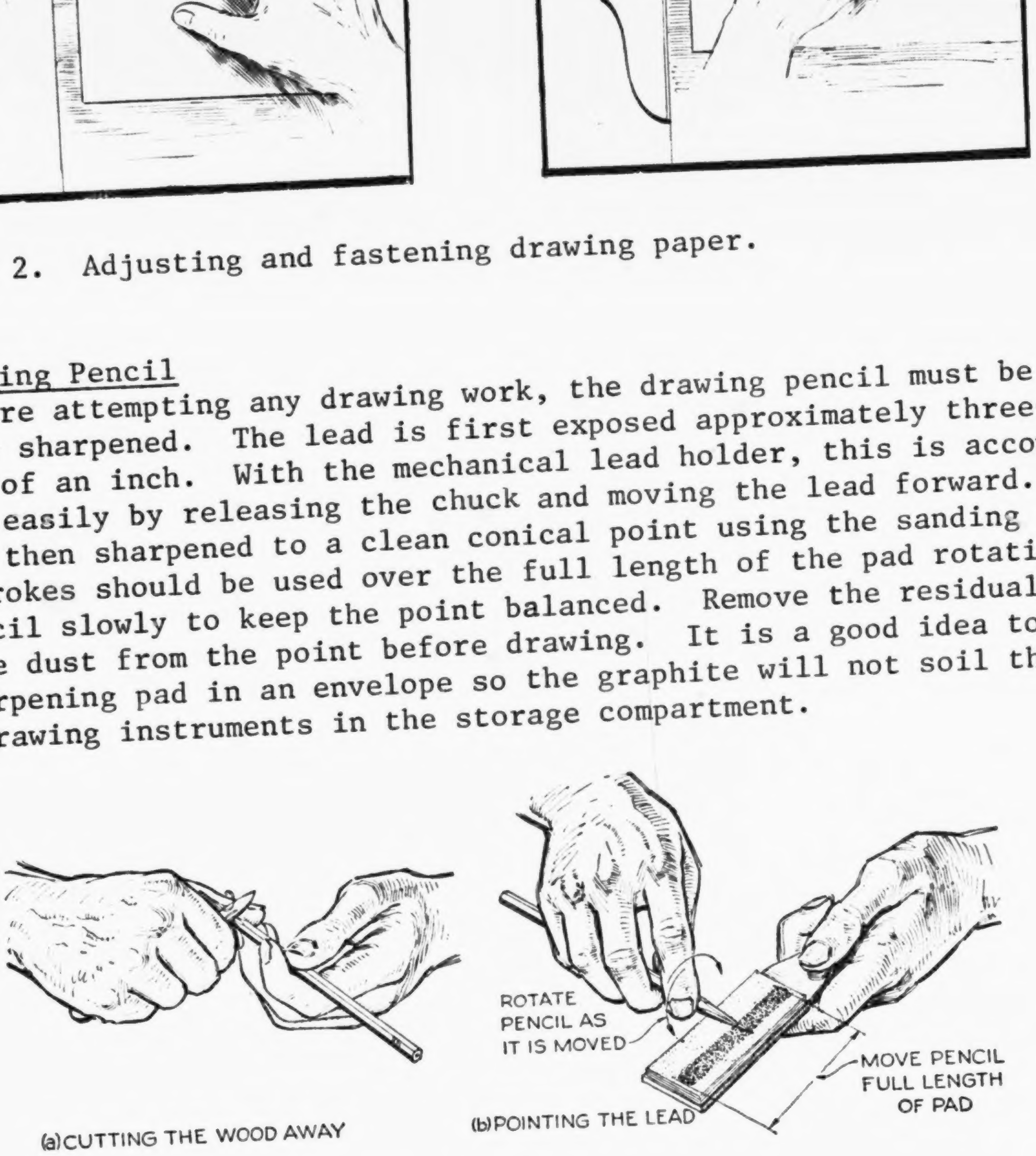


Figure 2. Adjusting and fastening drawing paper.

The Drawing Pencil

Before attempting any drawing work, the drawing pencil must be properly sharpened. The lead is first exposed approximately three-eighths of an inch. With the mechanical lead holder, this is accomplished easily by releasing the chuck and moving the lead forward. The lead is then sharpened to a clean conical point using the sanding pad. Long strokes should be used over the full length of the pad rotating the pencil slowly to keep the point balanced. Remove the residual graphite dust from the point before drawing. It is a good idea to keep the sharpening pad in an envelope so the graphite will not soil the other drawing instruments in the storage compartment.


ROTATE PENCIL AS IT IS MOVED
MOVE PENCIL FULL LENGTH OF PAD

(a)CUTTING THE WOOD AWAY

(b)POINTING THE LEAD

Figure 3. Sharpening the pencil.

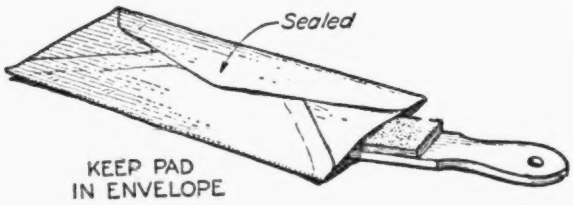


Figure 4. Preventing soiled drawing instruments.

A "screwdriver" or "wedge" point may be produced by flattening one or both sides of the lead on the sharpening pad. This type of point is useful where long lines are to be drawn, maintaining the point at a constant thickness over a longer period of time.

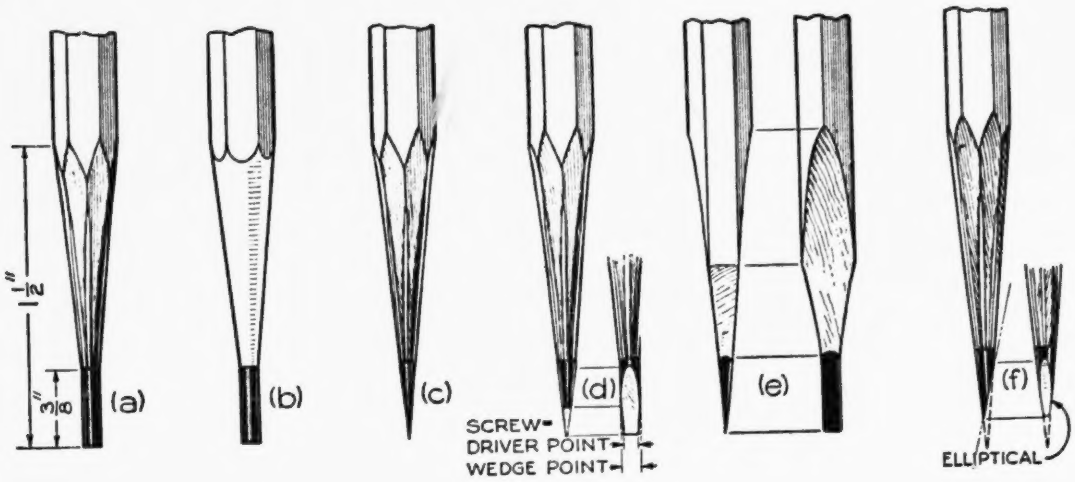


Figure 5. Pencil points.

Borderlines

No guarantee is made that the drawing paper is exactly "square" on all sides. Therefore, it is necessary to place a heavy borderline on the page limiting the drawing area. The borderline acts as a frame around the page within which all information is placed.

The width of the border is determined by the size of the drawing paper used. American Standard trimmed sizes of paper are based on either of two basic sizes, $8\frac{1}{2}$"x11" or 9"x12". Larger sheets are simply multiples of these sizes, as follows:

SHEET SIZE	$8\frac{1}{2}$"x11" STD	9"x12" STD
A	$8\frac{1}{2}$ x 11	9 x 12
B	11 x 17	12 x 18
C	17 x 22	18 x 24
D	22 x 34	24 x 36

A maximum border size of one-half inch is used for all standard industrial drafting,with smaller borders used on single-detail sheets (size A). For your drawings, a quarter-inch border will be used on size A and a half-inch border on size B. Using the standard 12-inch scale provided on the architect's scale, mark off the desired border width placing only one mark on each of the four sides of the paper.

Drawing Horizontal and Vertical Lines

All horizontal lines are drawn using only the top edge of the T-square blade. Starting at one side of the paper where the border will form a corner, hold the pencil at a 60° angle to the paper and rotate the pencil slowly as the line is drawn smoothly and somewhat rapidly across the page against the blade of the T-square. Rotating the pencil will help maintain a constant line width.

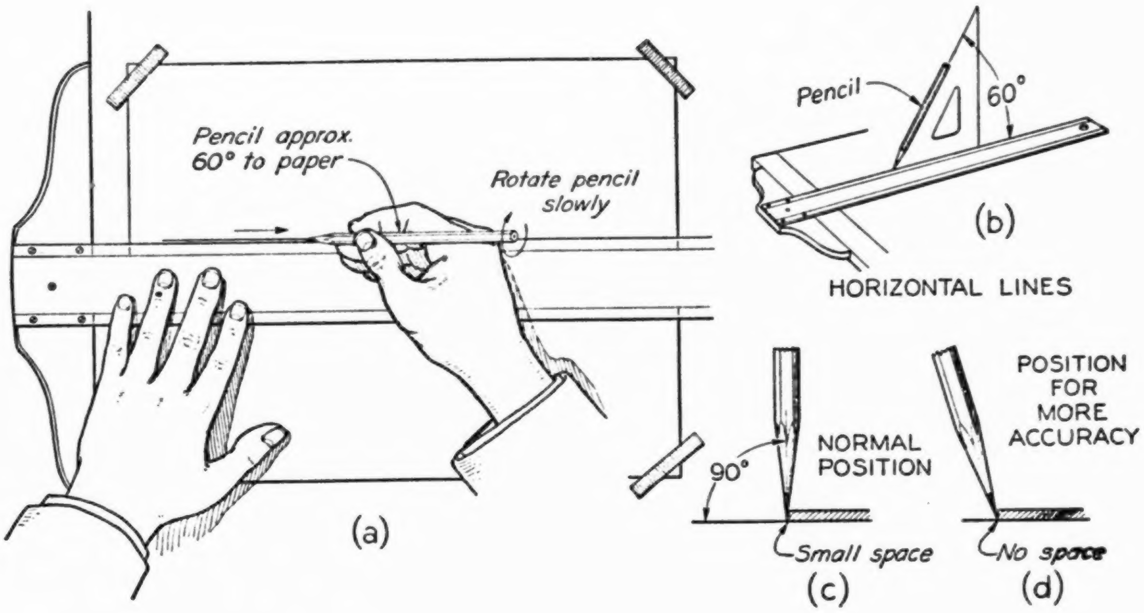

Pencil approx. 60° to paper
Rotate pencil slowly
(a)
Pencil
60°
(b)
HORIZONTAL LINES
90°
NORMAL POSITION
POSITION FOR MORE ACCURACY
Small space
No space
(c)
(d)

Figure 6. Drawing horizontal lines.

After placing both horizontal lines, position the triangle against the T-square with the vertical edge opposite the drawing hand. Hold both the T-square and triangle in position as vertical lines are drawn, usually from the bottom to the top of the page.

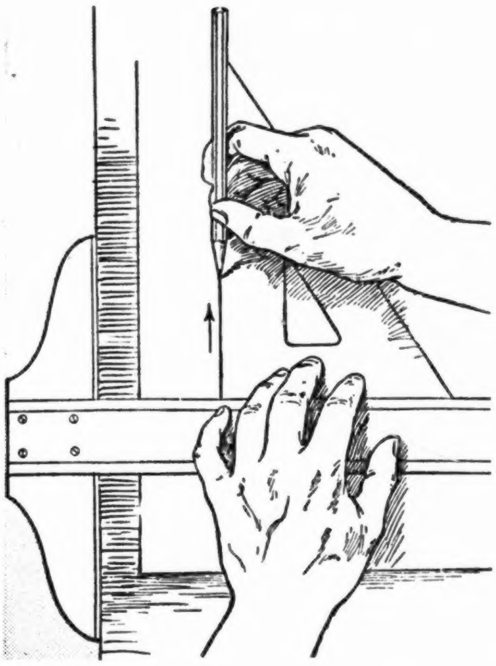


Figure 7. Drawing vertical lines.

You must be sure the T-square is placed securely against the board. Be sure that all lines fall directly on the marks measured previously with the scale. Providing the correct clearance for the pencil point to place lines exactly on location should be mastered from the beginning.

Drawing Inclined Lines

In addition to drawing vertical lines, the triangles are used to draw inclined lines by placing them against the T-square in various positions. The triangles may be used singly or in combination to draw angles in 15° increments from 0° to 90° in any direction on the page. Triangles are used in reversed position for angles drawn from other directions.

ASSIGNMENT:

1. Check the position of the table top and board. Be sure that the drawing board does not "rock".
2. Practice the positioning and taping of the drawing paper on your board.
3. Which hand do you use when drawing? On which side of the board will the head of the T-square be placed?
4. What type of point is normally used on drawing pencils?
5. Toward which side of your board will the vertical edge of the triangle be placed for drawing vertical lines?
6. What size border should be used on size C drawing paper?
7. At what angle should the pencil be tilted toward the direction to which lines are drawn?
8. Why should the pencil be rotated as long lines are drawn?
9. Why don't you hold just the triangle when drawing vertical lines?
10. What percentage of rag content is present in your drawing paper?

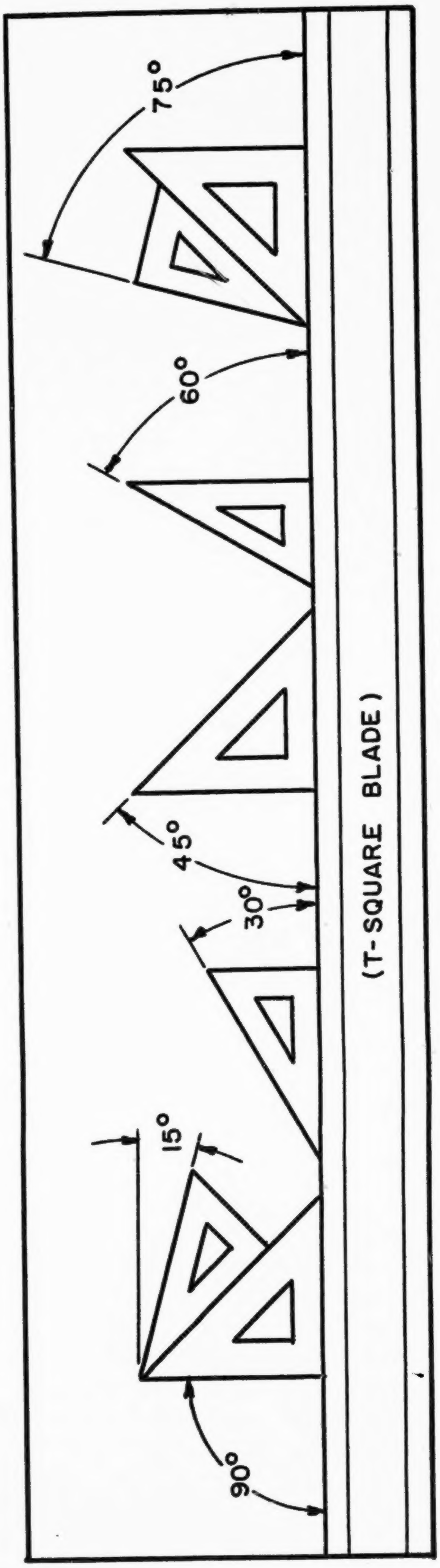


Figure 8. DRAWING INCLINED LINES

UNIT II - INTRODUCTION TO DRAWING

Drawing Layout and Identification

Lesson 2

OBJECTIVES:

1. To learn the importance of proper drawing identification.
2. To learn neatness and balance in drawing layout.
3. To introduce title block forms and their placement on drawings.
4. To introduce classroom drawing enumeration procedures and student identification systems.
5. To introduce the basic use of the scale.

REFERENCE:

1. Chapter 2 and 14, TECHNICAL DRAWING, Giesecke, Mitchell, and Spencer.

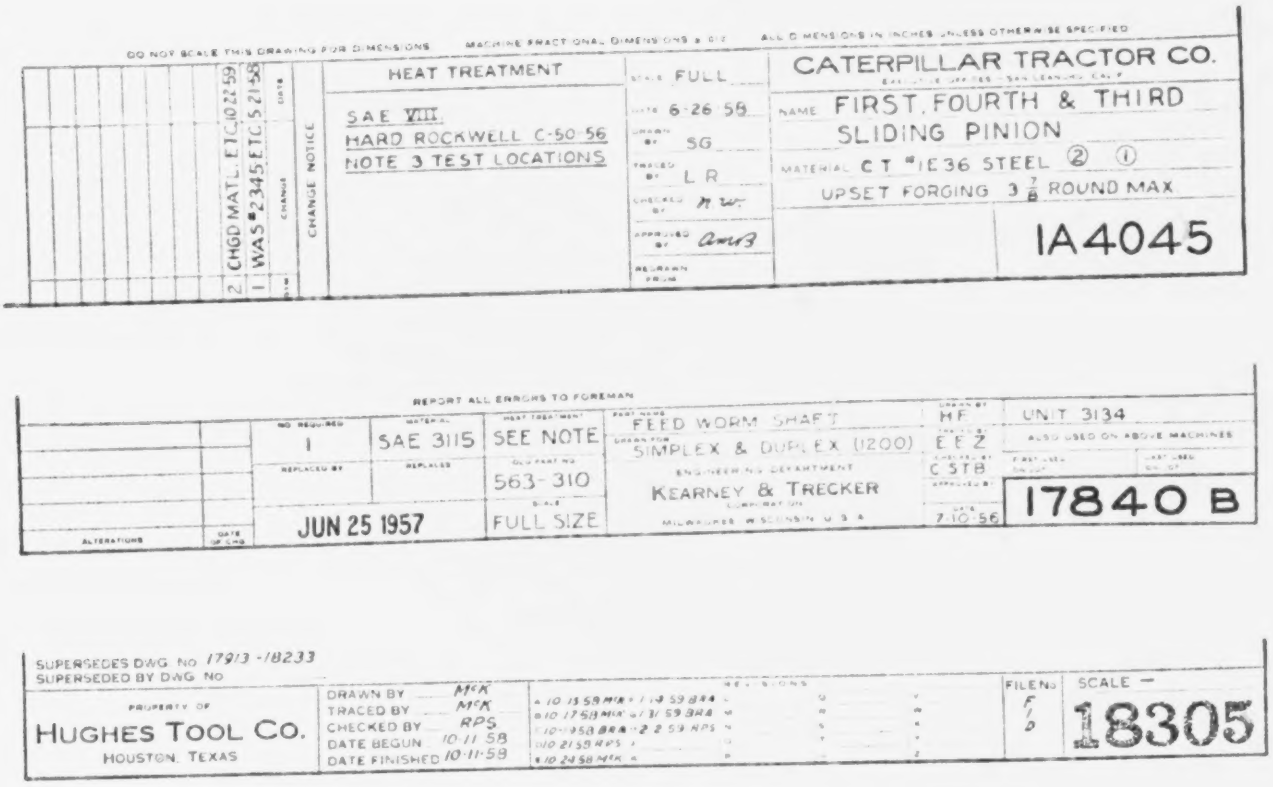
INFORMATION:

From the very beginning of your drafting experience, you learn techniques which apply to the production of working drawings. The use of title blocks on your drawings is one of these procedures.

There are many valid reasons supporting the use of title strips and various legends on working drawings. In general, the following information is given:

1. Name of the object represented.
2. Name and address of manufacturer.
3. Name and address of the purchasing company, if any.
4. Signature of the draftsman who made the drawing and the date of completion. (This is important since the draftsman is held responsible for the accuracy of his work.)
5. Signature of the tracer, if any, and the date of completion.
6. Signature of the checker and the date of completion.
7. Signature of the chief draftsman, chief engineer, or other official and the date of approval.
8. Scale of the drawing.
9. Number of the drawing.

Other information may be given such as material, quantity, notes on manufacturing procedures,and many other items depending on the industrial organization and the peculiarities of the product.



DO NOT SCALE THIS DRAWING FOR DIMENSIONS — MACHINE FRACTIONAL DIMENSIONS ± 1/64 — ALL DIMENSIONS IN INCHES UNLESS OTHERWISE SPECIFIED

2 CHGD MATL. ETC. 10-22-59
1 WAS #2345 ETC. 5-21-58
CHANGE NOTICE

HEAT TREATMENT
SAE VIII
HARD ROCKWELL C-50-56
NOTE 3 TEST LOCATIONS

SCALE FULL
DATE 6-26-58
DRAWN BY SG
TRACED BY L R
CHECKED BY n.w.
APPROVED BY

CATERPILLAR TRACTOR CO.
NAME FIRST, FOURTH & THIRD SLIDING PINION
MATERIAL C T #1E36 STEEL ② ①
UPSET FORGING 3 7/8 ROUND MAX
1A4045

REPORT ALL ERRORS TO FOREMAN
NO. REQUIRED 1
MATERIAL SAE 3115
HEAT TREATMENT SEE NOTE
OLD PART NO. 563-310
SCALE FULL SIZE
JUN 25 1957
PART NAME FEED WORM SHAFT
DRAWN FOR SIMPLEX & DUPLEX (1200)
ENGINEERING DEPARTMENT
KEARNEY & TRECKER CORPORATION
MILWAUKEE, WISCONSIN, U.S.A.
DRAWN BY HF
TRACED BY E E Z
CHECKED BY C STB
DATE 7-10-56
UNIT 3134
ALSO USED ON ABOVE MACHINES
17840 B
ALTERATIONS
DATE OF CHG.

SUPERSEDES DWG. NO. 17913-18233
SUPERSEDED BY DWG. NO.
PROPERTY OF
HUGHES TOOL CO.
HOUSTON, TEXAS
DRAWN BY McK
TRACED BY McK
CHECKED BY RPS
DATE BEGUN 10-11-58
DATE FINISHED 10-11-58
REVISIONS
FILE No. F/D
SCALE —
18305

Figure 1. Typical Industrial Title Strips

Placement of Title Blocks

The title form is usually placed in the lower right-hand corner of the sheet or along the bottom of the sheet, because drawings are usually placed in flat file drawers, and the title must be found easily.

You will be following the same procedure in placing your title block forms. Be sure you have first established the border for the drawings before attempting to place the block.

Style of Title Block

As you can see in figures 2 and 3, numerous layouts are possible for title strips. The factor which determines the ultimate form is the information which must be included.

Two basic forms will be used on your classroom drawings. The smaller form generally will be used on all introductory work, and the larger form will be used on all working drawings. Specific requirements for use will be outlined with each assignment.

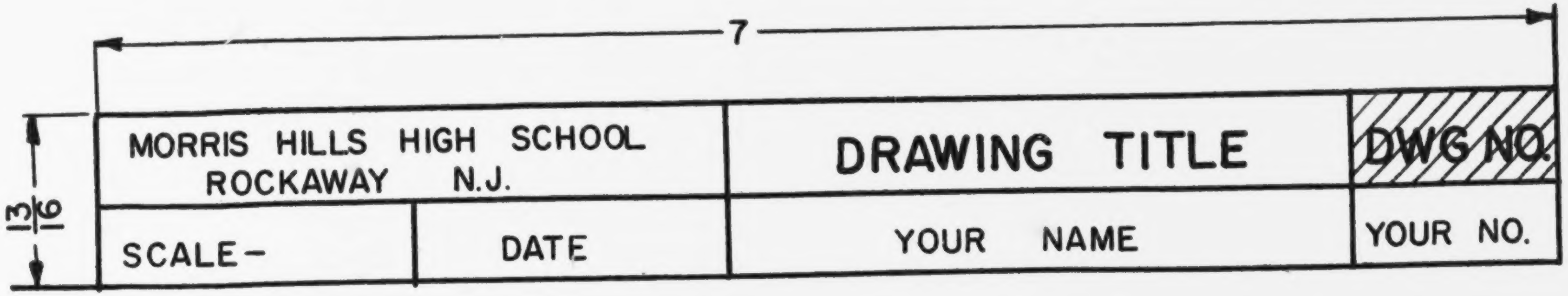

7
$\frac{13}{16}$
MORRIS HILLS HIGH SCHOOL
ROCKAWAY N.J.
DRAWING TITLE
DWG NO.
SCALE-
DATE
YOUR NAME
YOUR NO.

Figure 2. Simplified Title Block
(use $\frac{3}{16}$" numerals in shaded area)

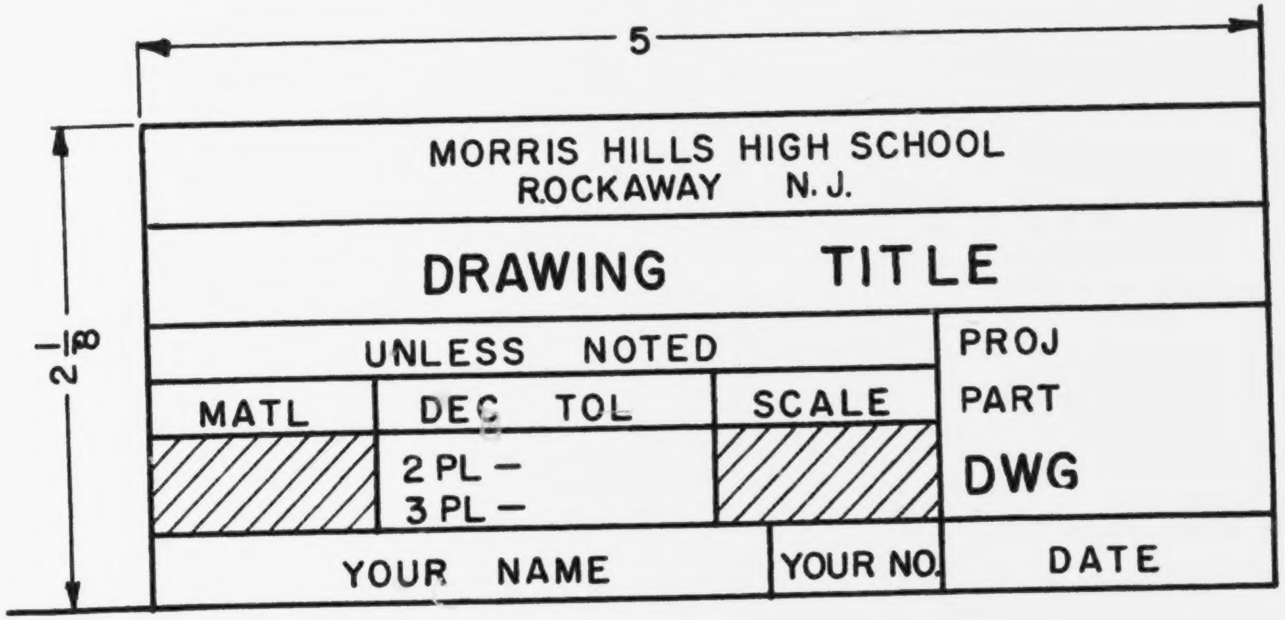

5
$2\frac{1}{8}$
MORRIS HILLS HIGH SCHOOL
ROCKAWAY N.J.
DRAWING TITLE
UNLESS NOTED
MATL
DEC TOL
SCALE
2 PL –
3 PL –
PROJ
PART
DWG
YOUR NAME
YOUR NO.
DATE

Figure 3. Working Drawing Title Block
(use $\frac{3}{16}$" lettering in shaded areas)

Title Block Lettering

The following lesson will deal with the formation of letters and numerals in detail. Certain facts concerning lettering in title blocks should be kept in mind:

1. Lettering should be single-stroke vertical Gothic capitals.
2. The items in the title form should be lettered in accordance with their relative importance.
3. The name of the school or company and the drawing number and the title should receive the greatest emphasis.
4. The date, scale, and draftsman's name are important but should not be prominently placed.
5. Greater importance of items is indicated by heavier or larger lettering, wider spacing of letters, or by a combination of these methods.

Note. Two lettering sizes will be used on your drawings, $\frac{1}{8}$" and $\frac{3}{16}$". Their usage can be seen in figures 2 and 3.

Placing Guide Lines

Guide lines must be established before any lettering may be done. A good draftsman never attempts to letter or enumerate any part of a drawing without first establishing guide lines.

In lettering your title block, establish guide lines centered vertically in each available space.

Use of Scale

The placement of your title block and measuring for all guide lines will be done using the standard 12-inch scale.

Learn to use the scale properly in order to maintain accuracy and convenience in its use. The following steps should be employed for all drawings as well as for title blocks:

1. Do not take measurements directly from the scale with the dividers or compass, as this will damage the scale.
2. Place the scale on the drawing parallel to the line on which the measurement is to be made. With a sharp pencil, having a conical point, make a short dash at right angles to the scale and opposite the graduation mark.
3. AVOID CUMULATIVE ERRORS in the use of the scale. If a number of distances are to be set off, all should be set off at one setting of the scale by adding each successive measurement to the preceding one. Avoid setting off the distances individually by moving the scale to a new position each time, since slight errors in the measurements may accumulate and result in a larger error.
4. Always use the scale in either of two basic positions: (a) held horizontally and read from the bottom of the page or; (b) held

vertically, reading from the right side. In these positions, the scale can be read beginning at either end to measure the desired distances.

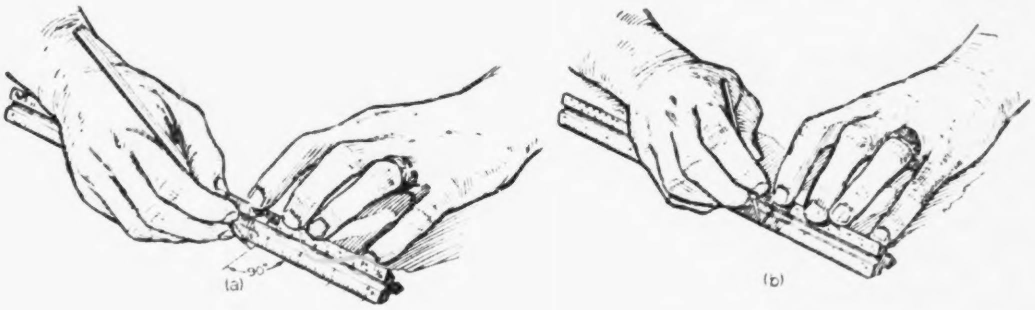
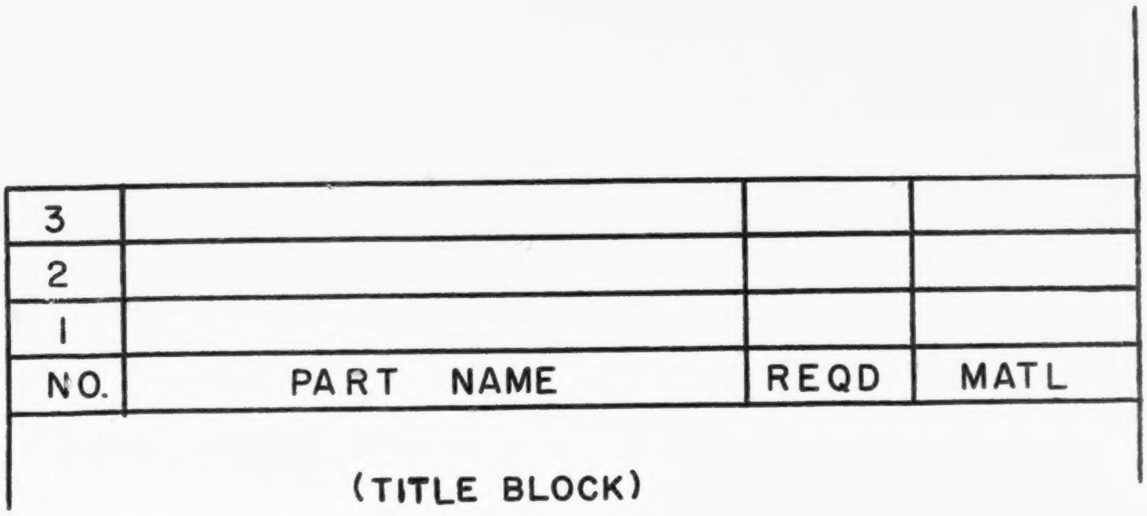


Figure 4. Making accurate measurements.

Parts Lists and Legends

Figures 5 and 6 show the basic format you will use for parts listings and hole legends as they are required in later working drawings. The parts list generally is placed directly above the title block, but can be placed at the upper right-hand corner when spacing and balance of the drawing necessitates an alternate position. The hole legend should be placed to the left of the title block against the lower border.

Information included in the parts list or the hole legend should be read starting from the border of the drawing, reading toward the center of the page. When the parts list is against the title block, the information is listed from the bottom up; and when the list is placed at the top border, the list is read from the top down. The hole legend is read from the border upward due to its position at the bottom of the page.



3			
2			
1			
NO.	PART NAME	REQD	MATL

(TITLE BLOCK)

Figure 5. Parts List Format

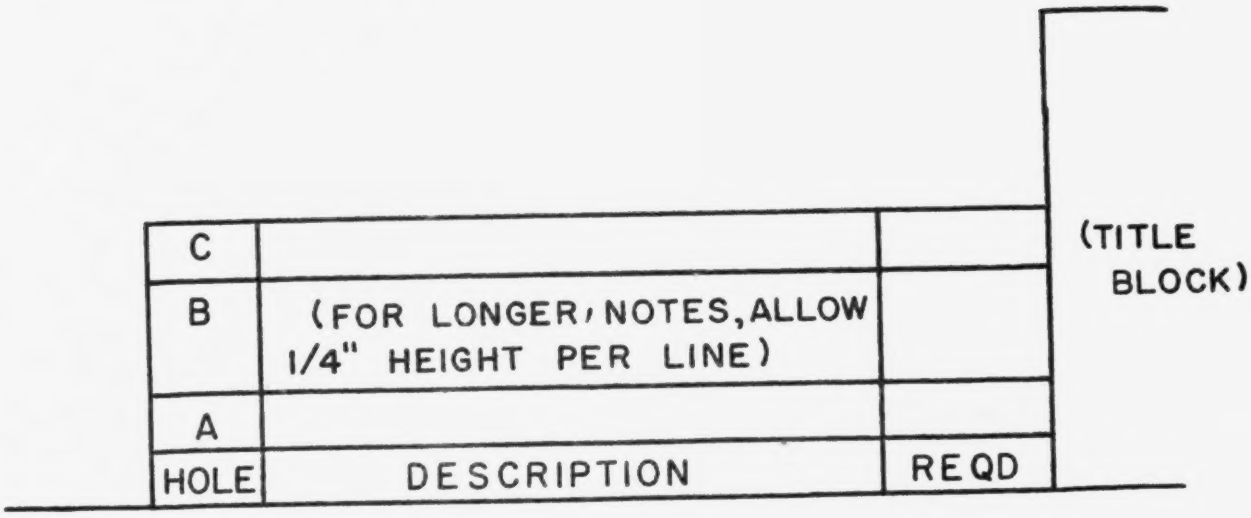


Figure 6. Hole Legend Format

Listing of Parts

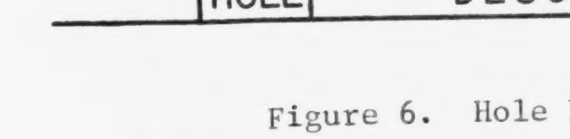
Parts are listed in general order of size and importance in working drawings, as:

1. The main castings or forgings.
2. Parts cut from cold-rolled stock followed by those of other materials.
3. Standard parts.

Extend the parts list only as far as is required by the content of each drawing. No parts list is required for single-detail drawings.

Identification Numbers

Identification numbers are used in conjunction with the parts list on all multiple-detail drawings. Each part is numbered in general order of importance and encircled. These circled numbers are placed next to the detail on the drawing.



The smaller size is used on size "A" sheets and the larger numbers on size "B" and larger sheets of paper.

Figure 7. Identification Numbers

Student Identification Numbers

An identification number will be assigned to you at the beginning of the term. The purpose of this number is to identify your class period and seat number, thus avoiding additional work on your title block. Place this number in the space provided in the title strip on every drawing.

Drawing Numbers

Unless otherwise specified, all drawings will be numbered consecutively from the beginning of the year. Instructions for project numbers and part numbers will be given with each drawing assignment.

ASSIGNMENT:

1. Where is your title block placed on the drawing?
2. Why is the draftsman's signature important on a drawing?
3. What is your identification number, and where is it used?
4. Explain the position in which the scale is used for all measuring. Give reasons.
5. How is information placed and read on all parts lists or hole legends?

UNIT II - INTRODUCTION TO DRAWING

Lettering — Lesson 3

OBJECTIVES:

1. To establish quality requirements for lettering on drawings.
2. To outline vertical lettering procedures.

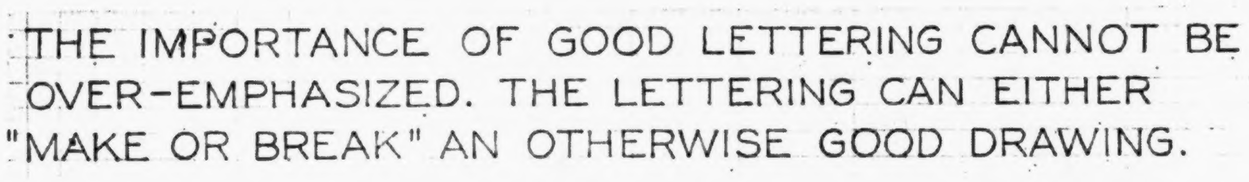
REFERENCES:

1. Chapter 3, MECHANICAL DRAWING, French and Svensen.
2. Chapter 3, TECHNICAL DRAWING, Giesecke, Mitchell, and Spencer.

INFORMATION:

Complete description of any machine or part requires the use of the GRAPHIC LANGUAGE to describe shapes and of the WRITTEN LANGUAGE to relate sizes, manufacturing methods, material, and other information.

An otherwise good drawing can be enhanced or destroyed by the amount of skill demonstrated in the lettering.

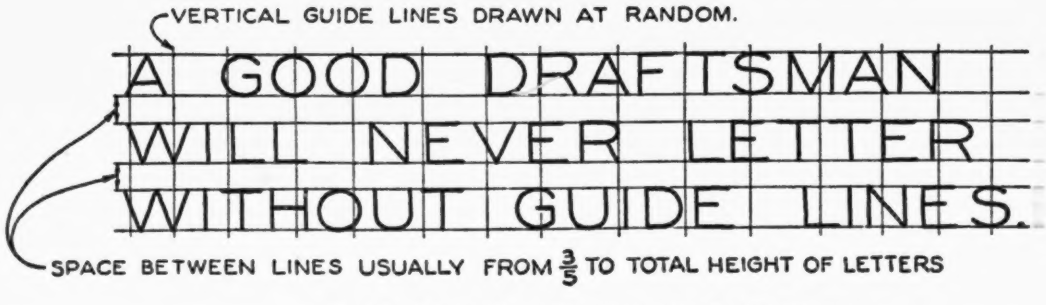


THE IMPORTANCE OF GOOD LETTERING CANNOT BE OVER-EMPHASIZED. THE LETTERING CAN EITHER "MAKE OR BREAK" AN OTHERWISE GOOD DRAWING.

Fig. 1

The use of guide lines, both vertical and horizontal, is important to good drawing. Horizontal guide lines are used to establish the height of all lettering and the dimensions. The T-square is used for all horizontal guide lines.

Throughout your drawing in this course, you will use American Standard letters of the vertical style. Effort must be made to follow exactly the construction of all letters and symbols (Figure 2).



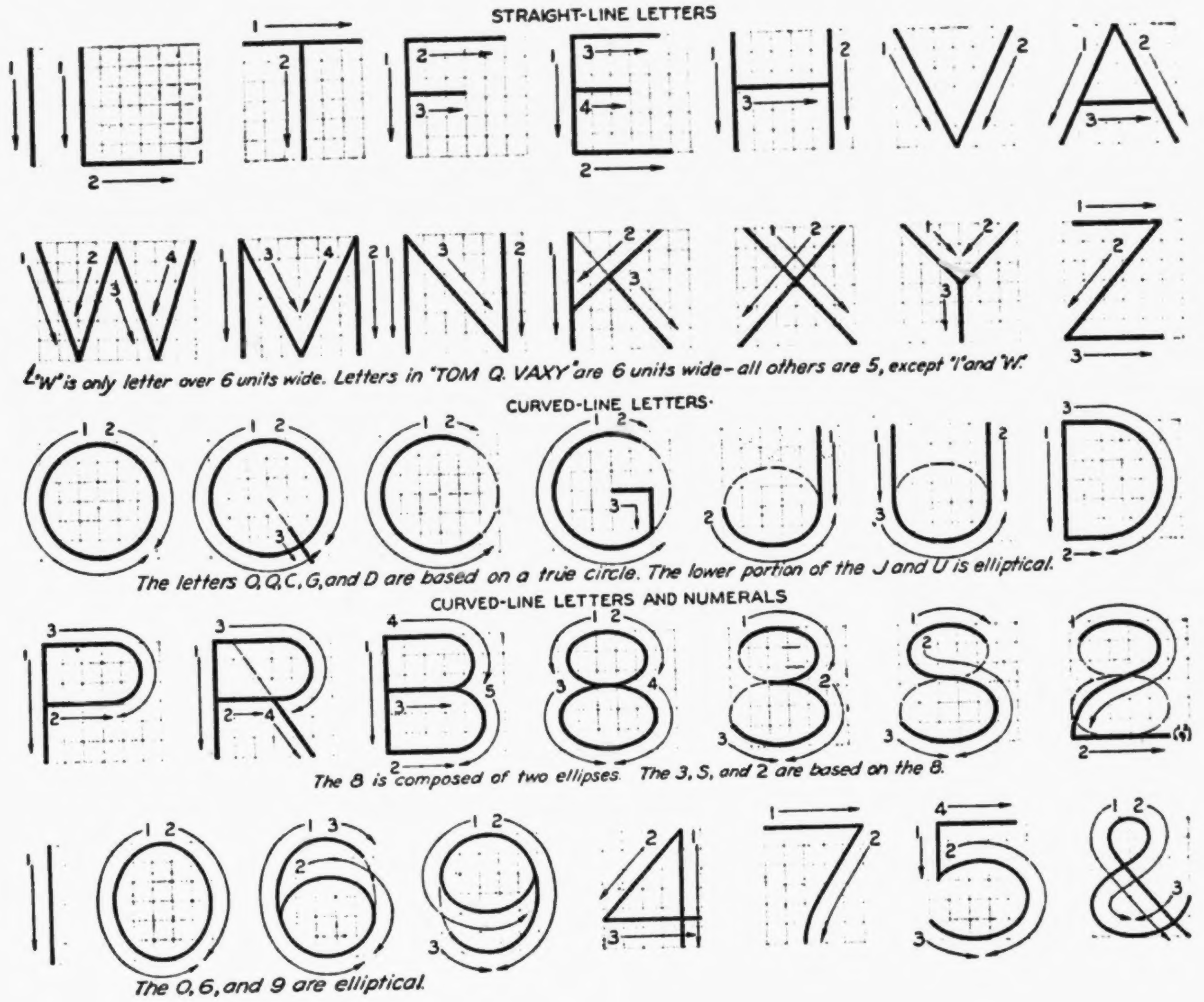
A GOOD DRAFTSMAN
WILL NEVER LETTER
WITHOUT GUIDE LINES.

VERTICAL GUIDE LINES DRAWN AT RANDOM.
SPACE BETWEEN LINES USUALLY FROM $\frac{3}{5}$ TO TOTAL HEIGHT OF LETTERS

Fig. 2

Guide Lines for Vertical Capital Letters.

Figure 3.


STRAIGHT-LINE LETTERS
"W" is only letter over 6 units wide. Letters in "TOM Q. VAXY" are 6 units wide - all others are 5, except "I" and "W".
CURVED-LINE LETTERS
The letters O, Q, C, G, and D are based on a true circle. The lower portion of the J and U is elliptical.
CURVED-LINE LETTERS AND NUMERALS
The 8 is composed of two ellipses. The 3, S, and 2 are based on the 8.
The O, 6, and 9 are elliptical.

Vertical Capital Letters and Numerals. For convenience in learning the proportions of the letters and numerals, each character is shown in a grid 6 units high. Numbered arrows indicate the order and direction of strokes. The widths of the letters can be easily remembered. The letter I, or the numeral 1, has no width. The W is 8 units wide ($1\frac{1}{3}$ times the height), and is the widest letter in the alphabet. All the other letters or numerals are either 5 or 6 units wide, and it is easy to remember the 6-unit letters because when assembled they spell TOM Q. VAXY. All numerals, except the 1, are 5 units wide.

All horizontal strokes are drawn to the right, and all vertical strokes are drawn downward. Most of the strokes are natural and easy to remember. All the strokes and proportions should be thoroughly learned in the beginning, and it is recommended that this be done by practice-sketching the vertical capital letters on cross-section paper, making the letters 6 squares high.

As shown the letters are classified as *straight-line letters* or *curved-line letters*. On the third row, the letters O, Q, C, and G are all based on the circle. The lower portions of the J and U are semi-ellipses, and the right sides of the D, P, R, and B are semicircular. The 8, 3, S, and 2 are all based on the figure 8, which is composed of a small ellipse over a larger ellipse. The 6 and 9 are based on the elliptical zero. The lower part of the 5 is also elliptical in shape.

All letters and numerals, with the exception of special requirements within the title block or in drawing fractions, will be $\frac{1}{8}$" in height. Requirements for fractions are illustrated in figure 4. Avoid common errors in making fractions outlined in figure 5. Guide lines should be very light and visible only one foot from the page.

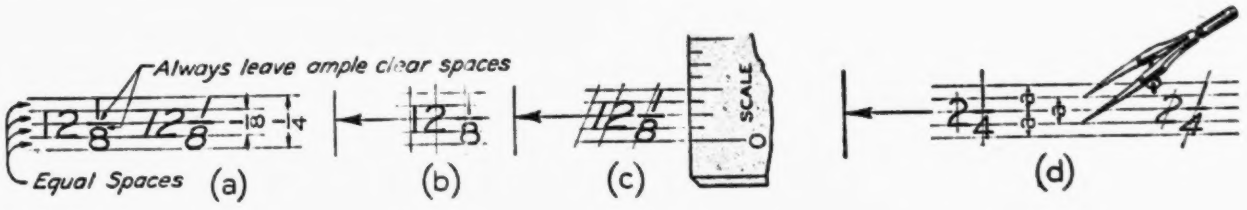

Always leave ample clear spaces
Equal Spaces
(a)
(b)
(c)
SCALE
(d)

Figure 4. Guide Lines for Dimension Figures

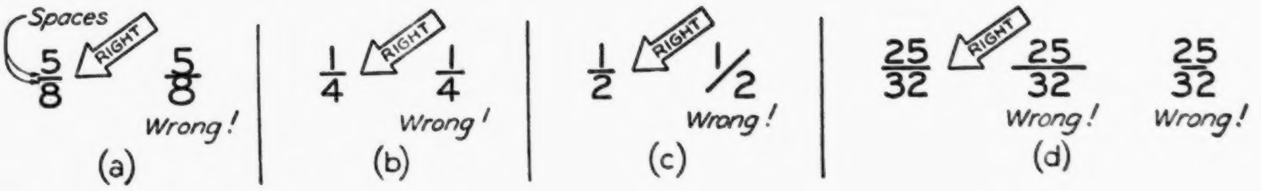

Spaces
RIGHT
Wrong!
(a)
(b)
(c)
(d)

Figure 5. Common Errors

Spacing Letters and Words

Uniformity in spacing of letters is a matter of equalizing spaces by eye. THE BACKGROUND AREAS BETWEEN LETTERS, NOT THE DISTANCE BETWEEN THEM, SHOULD BE APPROXIMATELY EQUAL. In figure 6(a) the actual distances are equal, but the letters do not appear equally spaced. In figure 6(b) the distances are intentionally unequal, but the background areas between letters are approximately equal; and the result is an even and pleasing spacing.

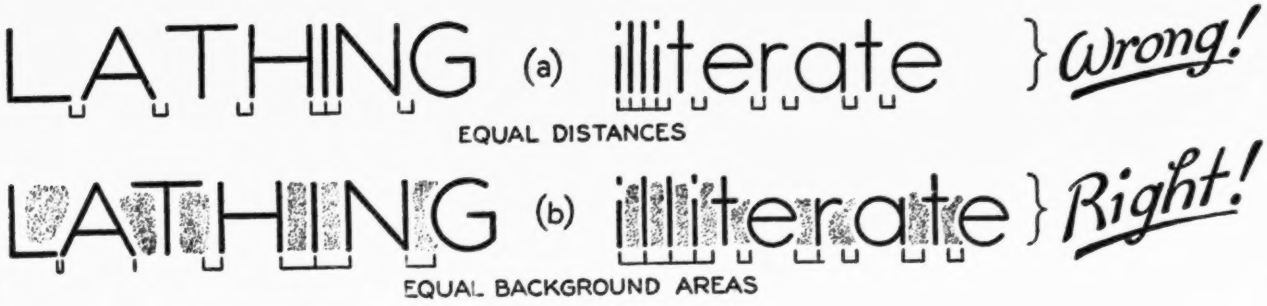

LATHING
(a)
illiterate
Wrong!
EQUAL DISTANCES
LATHING
(b)
illiterate
Right!
EQUAL BACKGROUND AREAS

Figure 6. Spacing between letters.

SPACE WORDS WELL APART, BUT SPACE LETTERS CLOSELY WITHIN WORDS. Make each word a compact unit well separated from adjacent words. Make spaces between words approximately equal to a capital O. Avoid spacing letters too far apart and words too close together.

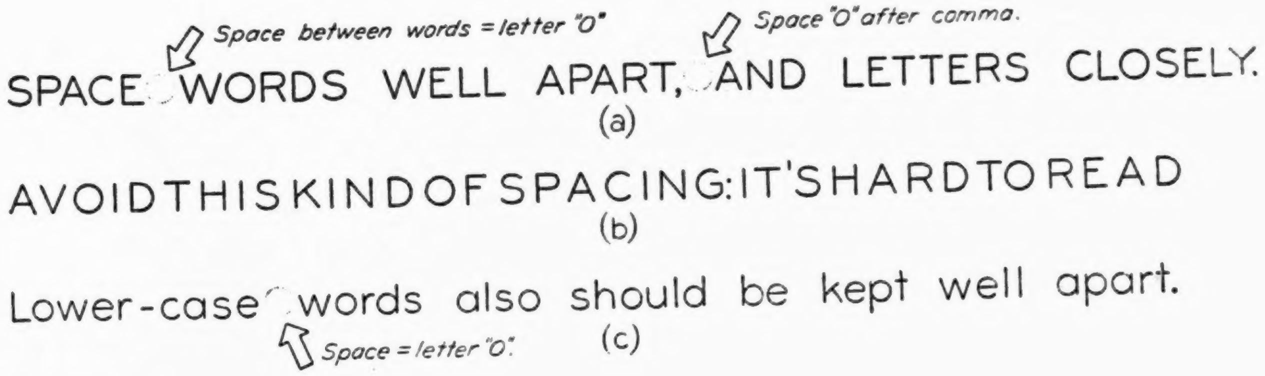

Space between words = letter "O"
Space "O" after comma.
SPACE WORDS WELL APART, AND LETTERS CLOSELY.
(a)
AVOIDTHISKINDOFSPACING:IT'SHARDTOREAD
(b)
Lower-case words also should be kept well apart.
Space = letter "O".
(c)

Figure 7. Spacing between words.

Practice of lettering on drawings combined with occasional exercises to correct errors are the only ways you will achieve quality in your work. Do not expect to letter perfectly the first time. Learn from your mistakes and make continuous efforts toward improvement. Do the best job you can each time and keep in mind the correct form for each of the letters as you draw them. Use vertical guide lines to keep lettering straight. Hard work is necessary to become proficient at lettering.

ASSIGNMENT:

1. Establish guide lines and letter your name, number, and the name of the school in your title block. Fill in other information as you complete the drawing.

2. Practice your lettering. Letter the alphabet and numerals three times, then your name and address. Continue three or four times through each. Be sure to establish correct guide lines or use graph paper.

3. Review the form of the letters you produced in No. 2. Compare them to the lettering chart in your text. Practice those letters which are not up to par.

Single-View Drawings

Lesson 4

OBJECTIVES:

1. To outline problem centering procedures.
2. To outline use of guide lines.
3. To introduce line weights and qualities.
4. To provide practice in the use of the T-square, triangles, scale, and pencil.

REFERENCES:

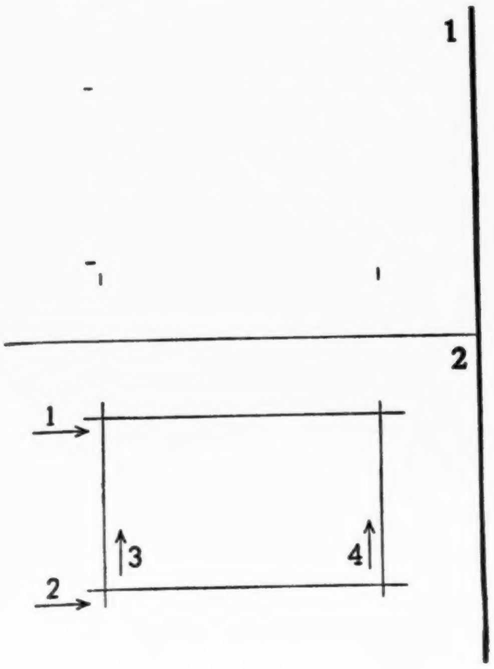
1. Chapter 24, MECHANICAL DRAWING, French and Svensen.
2. Chapter 5, TECHNICAL DRAWING, Giesecke, Mitchell, and Spencer.

INFORMATION:

Basic practice using the T-square and triangles together is necessary before technical work can progress. Previous to starting work, be sure your pencil is sharpened to a clean conical point and your T-square and triangles are clean and ready for use.

Following the mounting of your paper and the layout of borderlines and title block, consider the size of the available drawing area on the paper above the title block and between left and right borders. Consider the overall size of the view to be drawn and center it on the page by following these basic steps:

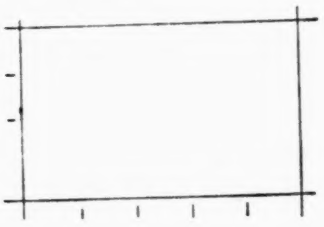
Figure 1.



Using your scale, measure the horizontal and vertical position of the total view. Use small marks to place the view. Calculate equal distances at left and right and at top and bottom of view area.

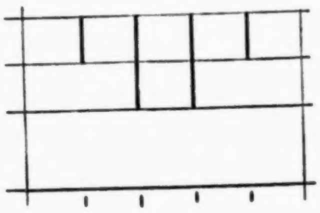
Draw light guide lines horizontally using the T-square and vertically using the triangle and the T-square, through the marks made in step 1. (Remember that the vertical edge of the triangle is opposite the drawing hand.)

3



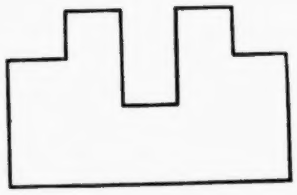
Mark off the horizontal and vertical subdivisions within the total limits of the object using the scale, and draw guide lines through these points as in step 2. (Guide lines are very light. Use only the weight of the pencil to make these lines. Do not move the scale while making the several measurements along each line.)

4



Considering the basic form of the object, draw object lines along all vertical edges. Stop at the necessary horizontal guide lines.

5



Complete the object by placing the horizontal object lines, and then, if necessary, erase any marks not wanted and brighten object lines to complete the drawing. Guide lines should not have to be erased, since they are originally very light.

Following the production of the drawing, fill in the title block giving all required information.

Alphabet of Lines

Quality of lines in drawings is extremely important. The use of the various line weights for specific purposes gives contrast to the drawing and will make it easy to read.

As can be seen in figure 2, three basic line weights are used for all drawing work; and by changing line structure, the lines serve various functions. Breaks within the lines have definite lengths and should be followed exactly.

Begin at this point to practice line weights to get the "feel" of how they are produced with your pencil. All lines should appear black, which is what is meant by "line quality." Not all lines are the same width, however, which is what is meant by the term "line weights."

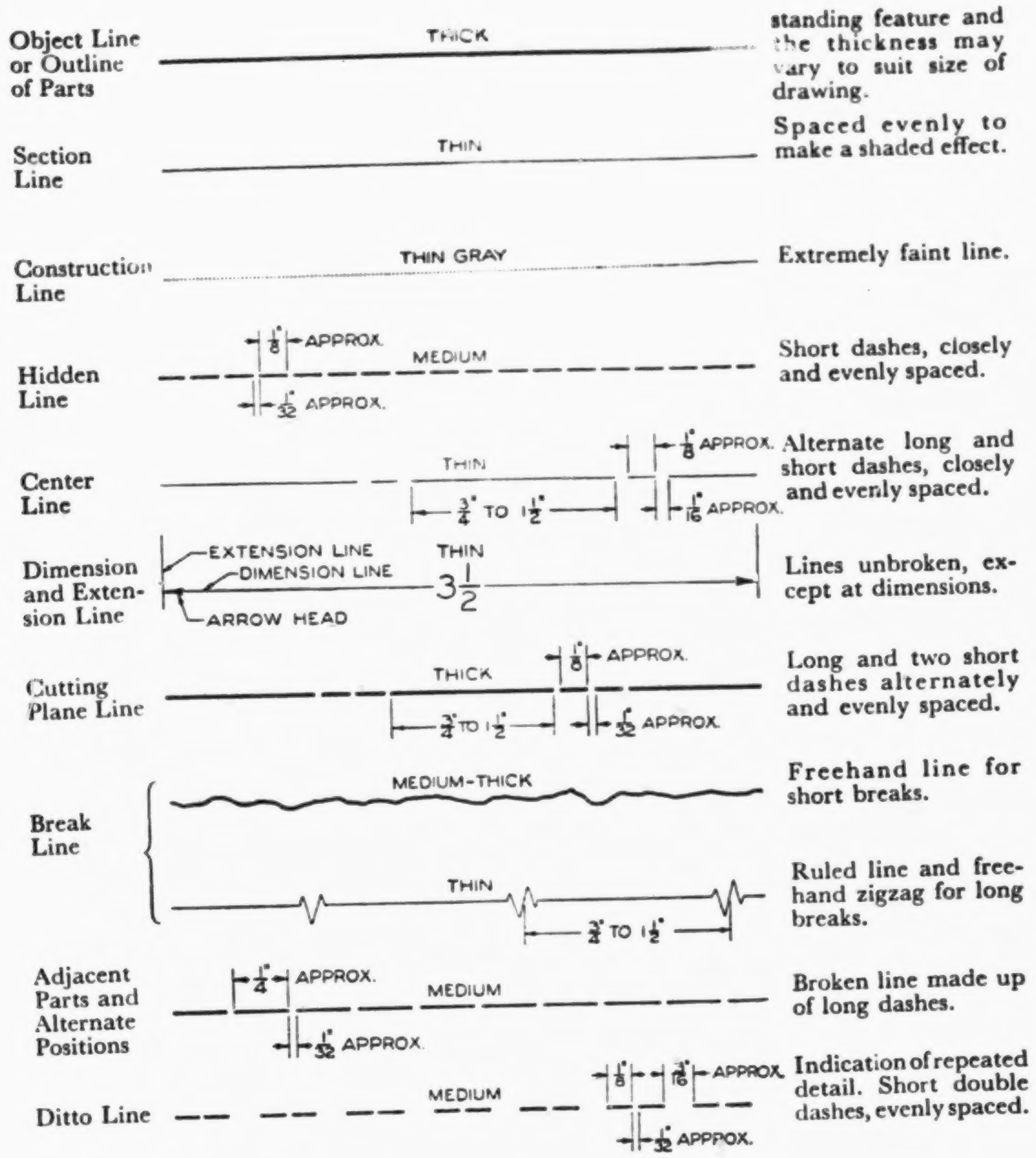

Object Line or Outline of Parts
THICK
standing feature and the thickness may vary to suit size of drawing.
Section Line
THIN
Spaced evenly to make a shaded effect.
Construction Line
THIN GRAY
Extremely faint line.
Hidden Line
1/8" APPROX.
MEDIUM
1/32" APPROX.
Short dashes, closely and evenly spaced.
Center Line
THIN
3/4" TO 1 1/2"
1/8" APPROX.
1/16" APPROX.
Alternate long and short dashes, closely and evenly spaced.
Dimension and Extension Line
EXTENSION LINE
DIMENSION LINE
ARROW HEAD
THIN
3 1/2
Lines unbroken, except at dimensions.
Cutting Plane Line
THICK
1/8" APPROX.
3/4" TO 1 1/2"
1/32" APPROX.
Long and two short dashes alternately and evenly spaced.
Break Line
MEDIUM-THICK
Freehand line for short breaks.
THIN
3/4" TO 1 1/2"
Ruled line and freehand zigzag for long breaks.
Adjacent Parts and Alternate Positions
1/4" APPROX.
MEDIUM
1/32" APPROX.
Broken line made up of long dashes.
Ditto Line
MEDIUM
1/8" 3/16" APPROX.
1/32" APPPOX.
Indication of repeated detail. Short double dashes, evenly spaced.

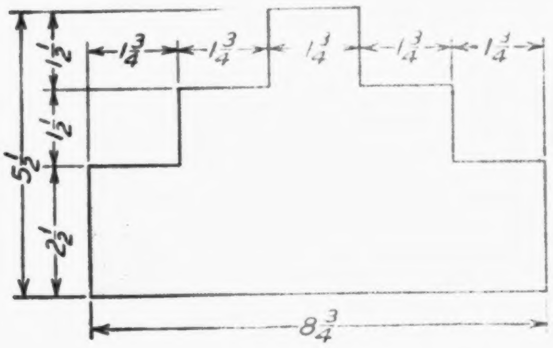
Figure 2. Alphabet of Lines (full size)

ASSIGNMENT:

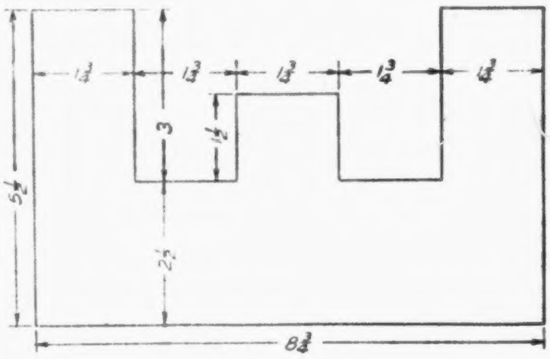
Following the layout procedures described in this lesson, draw each of the following exercises on size "A" drawing paper using the small title block form. Use quarter-inch borders on your paper. Omit all construction lines and dimension notes from the finished problem.

Problems 1 & 2 require the use of the T-square and right triangle.

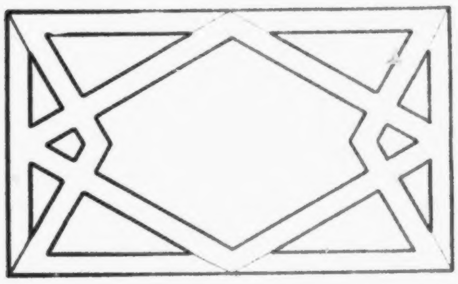
Problem 3 requires the 45° triangle and Problem 4 the 30°-60° **triangle.** The overall size of both problems is 3x5". **All lines are ¼"** apart, and the patterns are symmetrically centered.



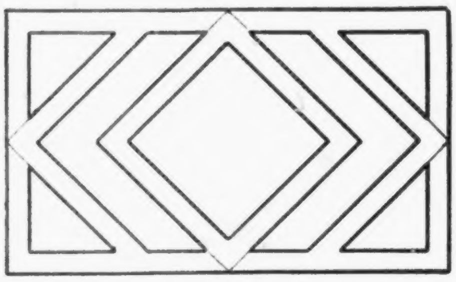
PROBLEM 1



PROBLEM 2

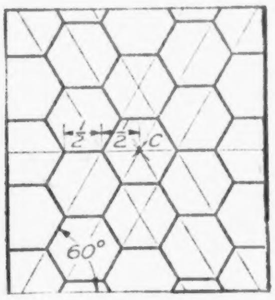


PROBLEM 3

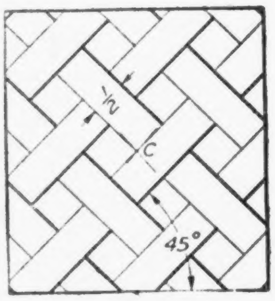


PROBLEM 4

Problems 5 & 6 are optional and may be done as time permits **before the** introduction of the next unit. Both exercises **are to be done** in a 5"-square area. The outline is to be **border-line quality.** Watch varied lines in problem 6.



PROBLEM 5



PROBLEM 6

It is to your advantage to do the best job you can on **each drawing and to do as** much drawing as possible to gain valuable **experience. DO NOT WASTE TIME.** Use time to your best advantage in developing **your skills in** drafting.

The Compass and Its Use Lesson 5

OBJECTIVES:

1. To relate proper adjustment and sharpening techniques.
2. To describe techniques of use.
3. To relate establishment of guide lines on drawings previous to compass usage.

REFERENCES:

1. Pages 33-34, MECHANICAL DRAWING, French and Svensen.
2. Pages 36-39, TECHNICAL DRAWING, Giesecke, Mitchell, and Spencer.

INFORMATION:

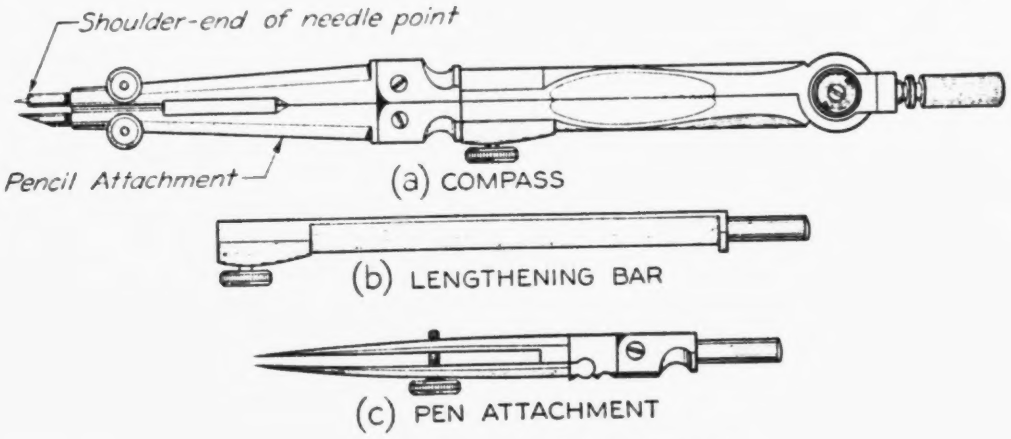

Shoulder-end of needle point
Pencil Attachment
(a) COMPASS
(b) LENGTHENING BAR
(c) PEN ATTACHMENT

Figure 1. **Compass and Attachments.**

The regular drawing compass has been in use for many years.

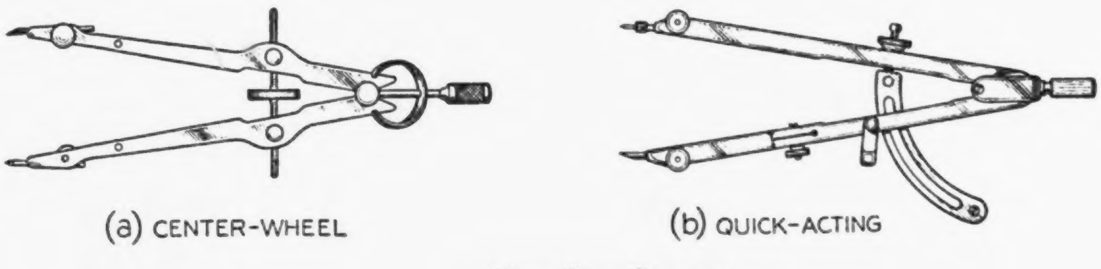

(a) CENTER-WHEEL
(b) QUICK-ACTING

Figure 2. **Giant Bow Compass.**

The giant bow compass has come into general use as a result of the needs of industry.

These compasses have proven to be more convenient to use, and they provide a secondary use as dividers by the simple placement of the needle points.

The compass is a delicate instrument and must be handled with care and used properly if quality work is to be continually produced.

Sharpening and Adjusting the Compass

Several types of points may be formed on the compass lead, the most common being a single elliptical face (figure 4a) formed by rubbing the lead on the sandpaper pad. This type of point is otherwise known as a chisel point. Figures 4b and 4c show how the point may be narrowed by small side cuts or formed similar to a screwdriver point if so desired. The form of the point is a matter of individual preference, as long as the point is sharpened on the outside of the instrument as shown in figure 4d.

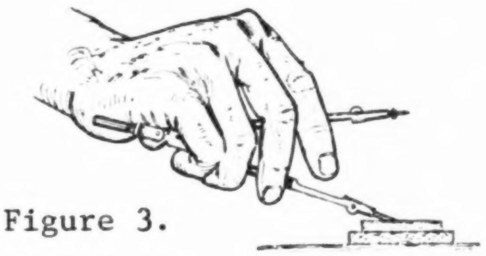


Figure 3. **Sharpening Compass Lead.**

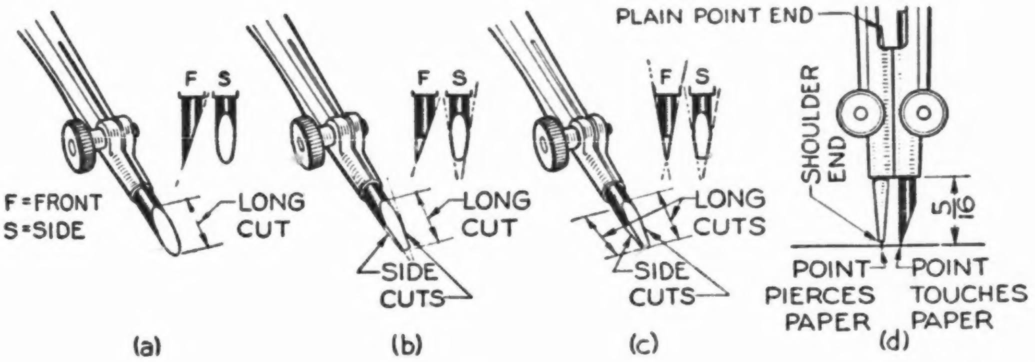


Figure 4. Compass Lead Points.

When setting the steel point in the compass, NEVER USE THE PLAIN END OR THE NEEDLE POINT. Instead, use the SHOULDER POINT (figure 4d) adjusted so that the tiny needle point extends about halfway into the paper when the compass lead just touches the paper. It is suggested that you USE LEAD WHICH IS A GRADE SOFTER than the lead in your pencil to avoid the need for repeated passes over the paper to attain the desired line quality.

Use of Compass as Dividers

When it is necessary to set off several equal distances on the page or to transfer distances from one drawing to another, the compass may be used as a divider (figure 5). PLACE THE NEEDLE POINTS ON BOTH LEGS of the compass and adjust the "setting" carefully. Small errors in spacing will be multiplied as a number of distances are set off on your drawing.

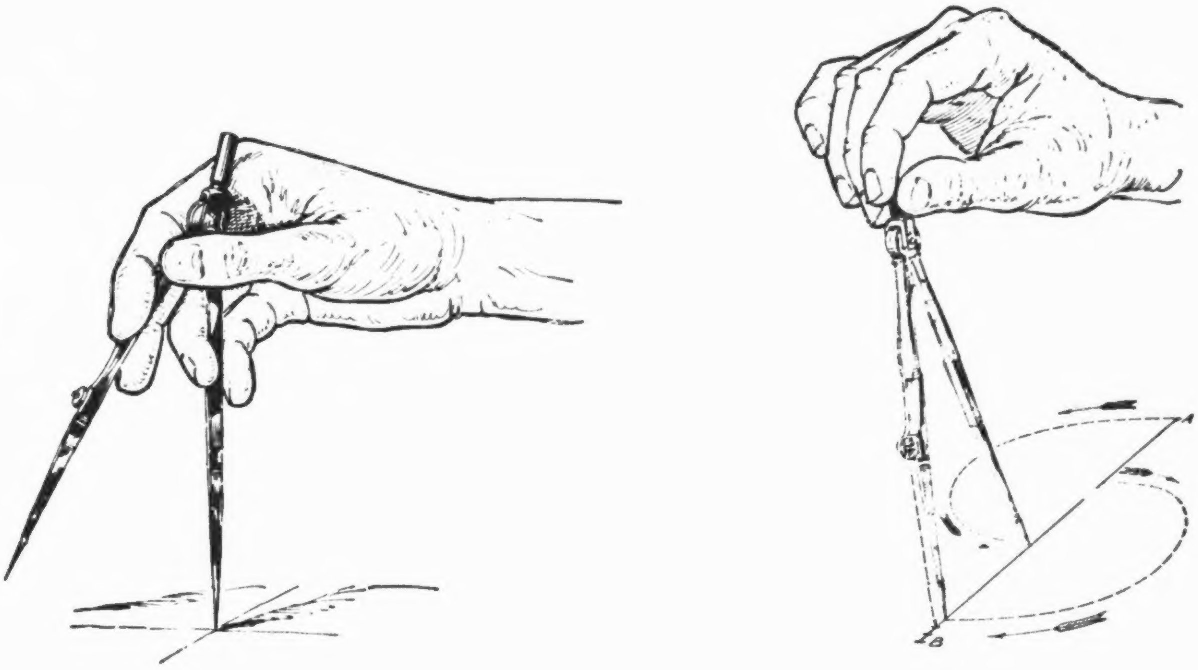


Figure 5. Adjusting and using the compass as a divider.

Drawing Large Radii

When it is necessary to draw large radii, a compass which provides a lengthening bar to increase the radius must be used. Figure 6 shows how the legs of the compass must be "broken" so that both points stand as perpendicular to the page as possible. Use both hands, but be careful not to jar the compass and thus change the adjustment.

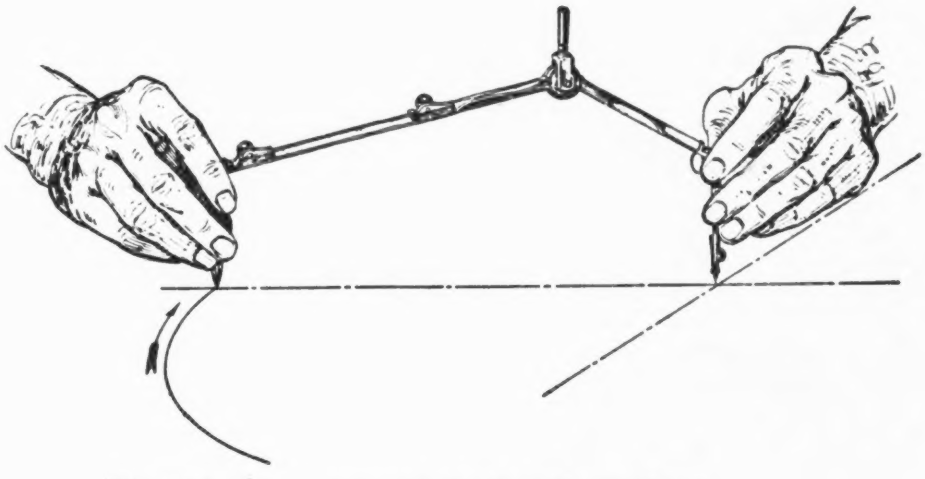


Figure 6. Drawing Circles of Large Radii.

Compass Usage in Drawing

Guide lines must be established before lines are drawn with the compass. Usually, the establishment of center lines with a mark along one center line indicating the correct radius will be all that is necessary. In some cases it may be advisable to work within a "squared" area for greater accuracy.

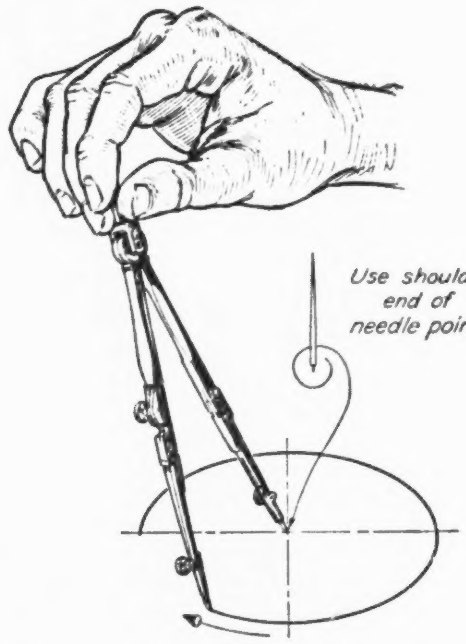


Figure 7. Using the drawing compass.

Once the center lines and radius have been determined, set the needle point at the exact intersection of the center lines. Adjust the compass to the required radius on the drawing, and lean the compass forward drawing the circle clockwise while rotating the handle between the thumb and forefinger. To obtain a sufficient weight of line, it may be necessary to repeat the movement several times.

Note. The large compass is used only for circles of one-inch or larger radius.

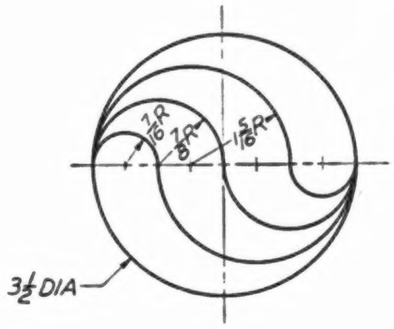
Curved Lines First

All arcs and circles on a drawing are completed first. It is much easier to connect straight lines to arcs than to do the reverse. For this reason, it is absolutely necessary that all guide lines for a drawing be completed before any object lines are drawn.

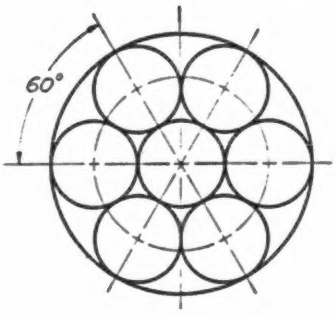
Never use the compass for constructing so-called "guide lines." Proper guide lines run either horizontally or vertically on the drawing. Whenever the compass is used, completed lines are produced. Coming back to complete a line will only lead to inaccuracy in your work, either by increasing the hole made by the shoulder point or by accidental placement of the point off-center.

ASSIGNMENT:

On size "A" drawing paper using the simplified title block form, do problems 1 and 2 in the available drawing area. Problem 1 is 3$\frac{1}{2}$" in diameter and Problem 2 is 3$\frac{3}{4}$" in diameter.



Problem 1.



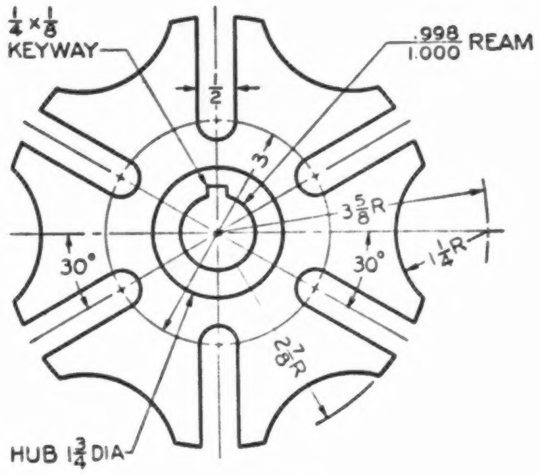
Problem 2.

Choose two problems from problems 3 through 6.

Do each problem on a separate size "A" sheet.

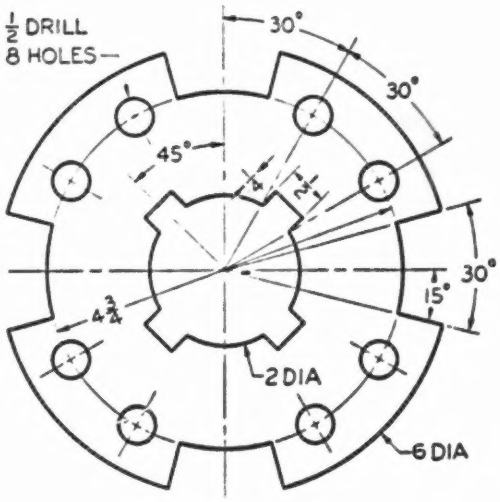
Use the titles given with each problem.

Note. Omit all dimensions and construction notes on the finished drawings.


1/4 × 1/8 KEYWAY
.998/1.000 REAM
1/2
3
3 5/8 R
1 1/4 R
30°
30°
2 7/8 R
HUB 1 3/4 DIA

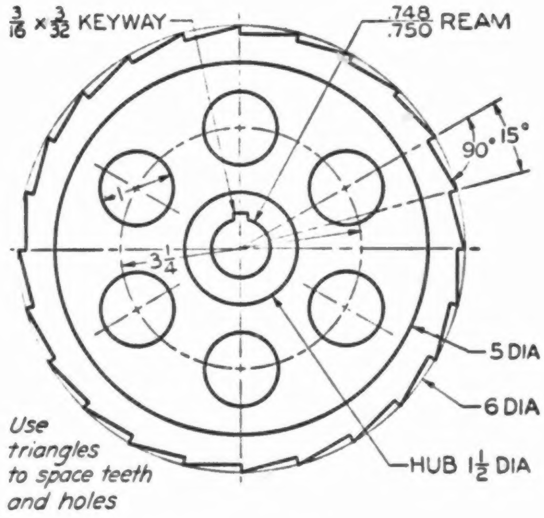
Geneva Cam.

Problem 3


1/2 DRILL 8 HOLES
30°
30°
45°
1/4
1/2
30°
15°
4 3/4
2 DIA
6 DIA

Friction Plate.

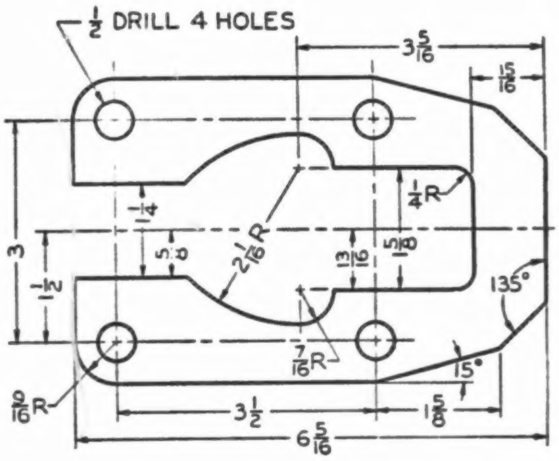
Problem 4


3/16 × 3/32 KEYWAY
.748/.750 REAM
90°
15°
1
3 1/4
5 DIA
6 DIA
HUB 1 1/2 DIA

Use triangles to space teeth and holes

Ratchet Wheel.

Problem 5


1/2 DRILL 4 HOLES
3 5/16
15/16
1/4 R
1 1/4
3
1 1/2
5/8
2 1/16 R
13/16
1 5/8
135°
7/16 R
15°
9/16 R
3 1/2
1 5/8
6 5/16

Latch Plate.

Problem 6

QUESTIONS:

1. Name two types of bow compasses.
2. What is the diameter of the smallest circle which should be drawn using the 6-inch compass?
3. What is the common name given to the sharpened lead point on your compass? What steel point is used in the compass?

4. How far should the lead extend beyond the leg of the compass?

5. What must be done before circles are drawn on the paper?

6. What is the largest radius you should attempt to draw using the 6-inch compass?

7. What do you do when larger radii have to be drawn?

8. What grade of lead should be used in the compass if 3H is used in your pencil?

9. What lines are drawn first, curved or straight lines?

10. What happens if a compass is opened beyond its intended limits?

UNIT II - INTRODUCTION TO DRAWING

Geometric Constructions — Lesson 6

OBJECTIVE:

1. To introduce basic geometric constructions applicable to future drawing assignments.

REFERENCES:

1. Chapter 4, MECHANICAL DRAWING, French and Svensen.
2. Chapter 4, TECHNICAL DRAWING, Giesecke, Mitchell, and Spencer.

INFORMATION:

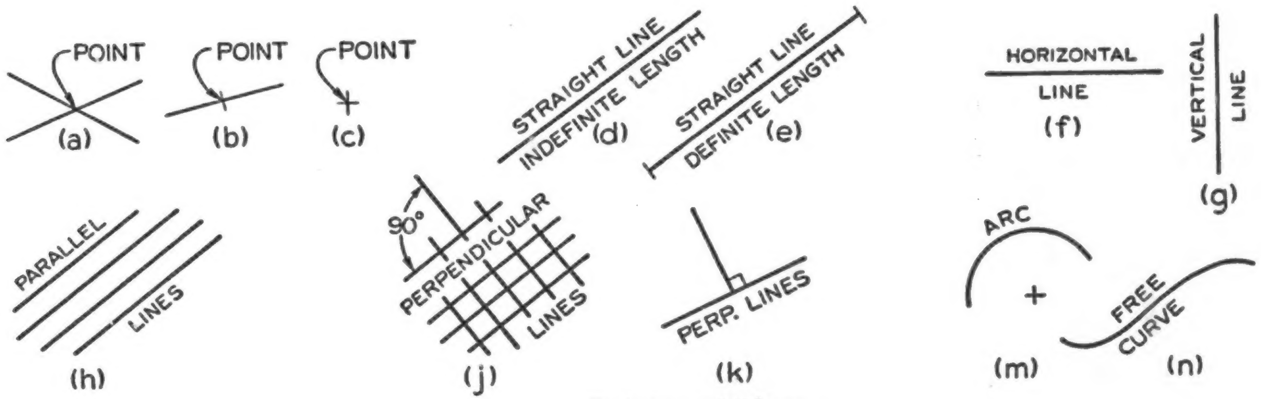
Most of the views required in mechanical drawings can be made by using the drawing instruments previously introduced without special consideration to procedures. However, it is sometimes necessary and more convenient to use geometric constructions.

The student should familiarize himself with the basic geometric constructions and learn of their use as an aid in making assigned drawings.

Related Definitions

Point - represents a location in space or on a drawing; has no width, height, or depth. It is represented by the intersection of two lines on a drawing.

Line - according to Euclid, "that which has length without breadth". A straight line is the shortest distance between two points. The end points must be fixed by intersecting lines.


POINT
POINT
POINT
(a)
(b)
(c)
STRAIGHT LINE
INDEFINITE LENGTH
(d)
STRAIGHT LINE
DEFINITE LENGTH
(e)
HORIZONTAL
LINE
(f)
VERTICAL
LINE
(g)
PARALLEL
LINES
(h)
90°
PERPENDICULAR
LINES
(j)
PERP. LINES
(k)
ARC
(m)
FREE
CURVE
(n)

Points and Lines.

Figure 1.

Parallel - straight or curved lines are parallel if the shortest distance between them remains constant.

Perpendicular - one line intersecting another at exactly 90° or a right angle.

Angle - the formation caused by the intersection of two lines. The opening between them is measured in degrees or $\frac{1}{360}$ of a full circle.

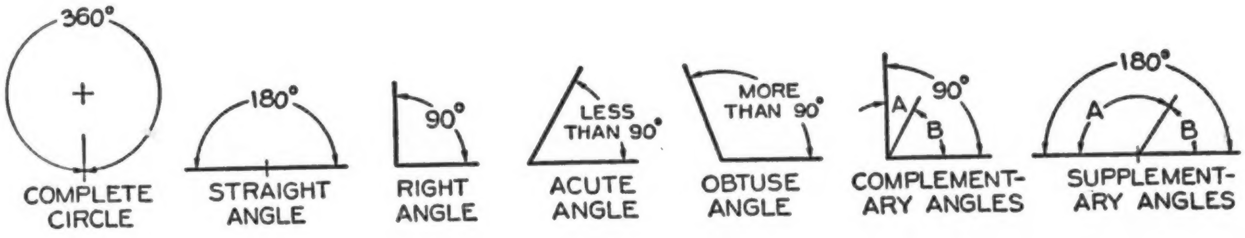

360°
COMPLETE CIRCLE
180°
STRAIGHT ANGLE
90°
RIGHT ANGLE
LESS THAN 90°
ACUTE ANGLE
MORE THAN 90°
OBTUSE ANGLE
A
B
90°
COMPLEMENTARY ANGLES
180°
A
B
SUPPLEMENTARY ANGLES

Figure 2. Angles

Triangle - a plane figure bounded by three straight sides; the sum of the interior angles is always 180°.

Polygons - Any plane figure bounded by straight sides. A "regular polygon" is one which has equal sides and angles and can be inscribed in or circumscribed by a circle.

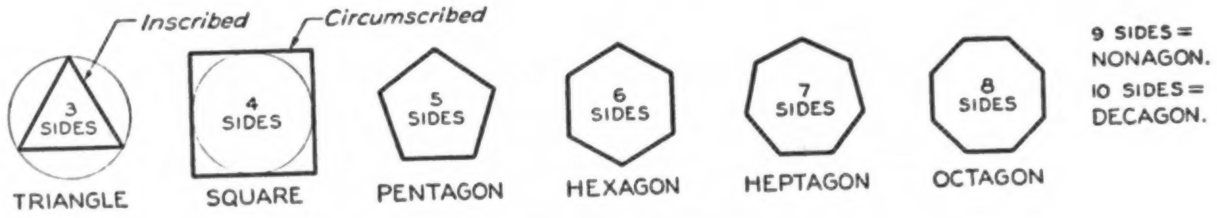

Inscribed
Circumscribed
3 SIDES
TRIANGLE
4 SIDES
SQUARE
5 SIDES
PENTAGON
6 SIDES
HEXAGON
7 SIDES
HEPTAGON
8 SIDES
OCTAGON
9 SIDES = NONAGON.
10 SIDES = DECAGON.

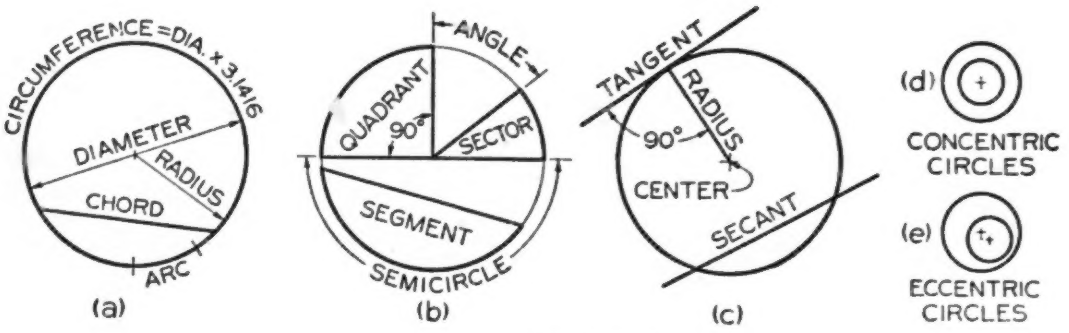
Figure 3. Polygons

Circle - a closed curve, all points of which are the same distance from a point called the "center".

Arc - A portion of a circle.

Diameter - the distance across a circle, measured along a line passing through the center.

Circumference - The distance around a circle. Equal to pi times the diameter. (Pi is equal to the factor 3.1416. This multiplied by the diameter gives the circumference of the circle.)


CIRCUMFERENCE=DIA. x 3.1416
DIAMETER
RADIUS
CHORD
ARC
(a)
ANGLE
QUADRANT
90°
SECTOR
SEGMENT
SEMICIRCLE
(b)
TANGENT
RADIUS
90°
CENTER
SECANT
(c)
(d)
CONCENTRIC CIRCLES
(e)
ECCENTRIC CIRCLES

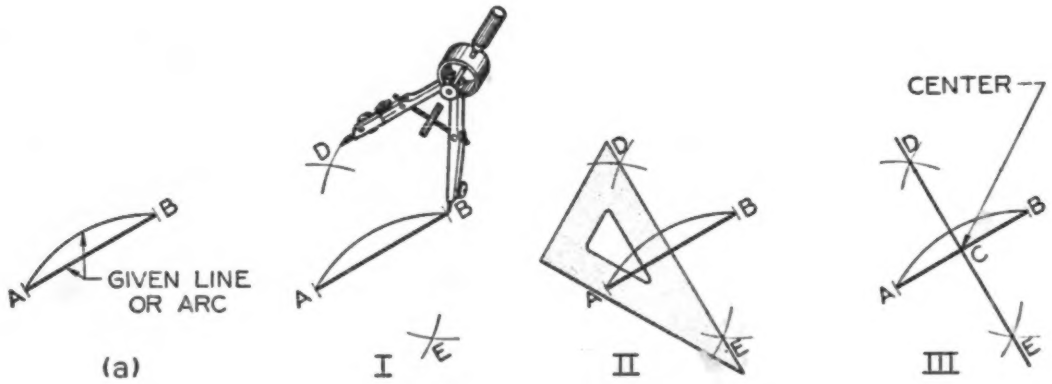
The Circle.

Figure 4.

The following paragraphs describe the various geometric constructions you will find applicable in drawing assignments.

To Bisect a Line or Circular Arc

Given line or arc AB, draw equal arcs with the radius greater than half AB. Join intersections D and E with a straight line to locate center C. Application - Locating centers for circle or the center point of a particular view.

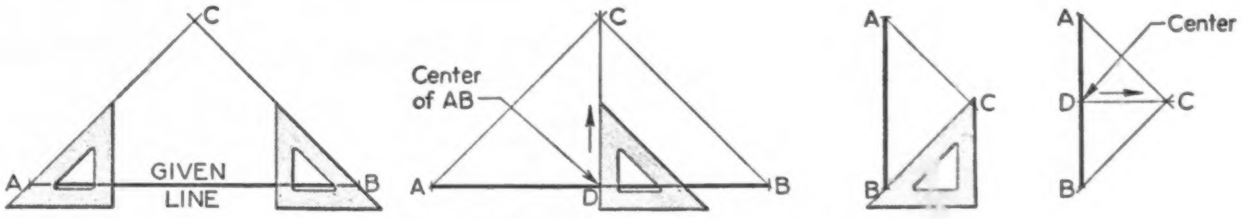

A
B
GIVEN LINE OR ARC
(a)
D
E
I
II
CENTER
C
III

Bisecting a Line or a Circular Arc

Figure 5.

Bisecting a Line with Triangle and T-square

From the ends of line AB, draw construction lines at 45° with the given line. Through the point of intersection C, draw a line perpendicular to the given line to locate center D.


C
A
GIVEN LINE
B
Center of AB
D
Center

Bisecting a Line with Triangle and T-square

Figure 6.

Bisecting an Angle

Given angle BAC, strike arc R. Strike equal arcs (R) with the radius slightly larger than one-half BC,to intersect at D. Draw line AD which bisects the angle.

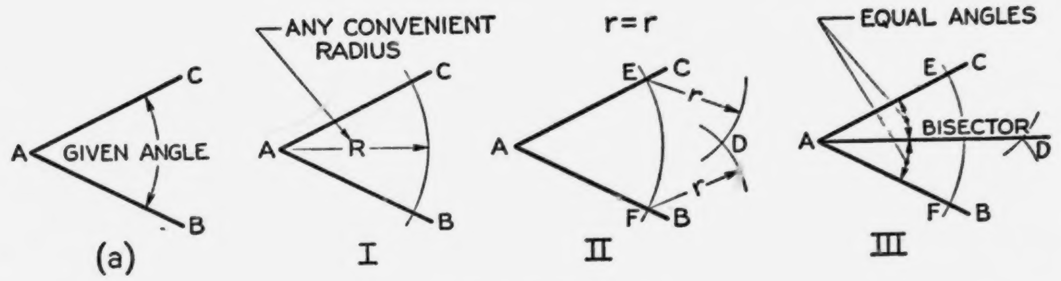

A
GIVEN ANGLE
C
B
(a)
ANY CONVENIENT RADIUS
A
R
C
B
I
r=r
A
E
C
r
D
r
F
B
II
EQUAL ANGLES
A
E
C
BISECTOR
D
F
B
III

Figure 7. **Bisecting an Angle**

To Draw Parallel Lines

Given line AB, align the instruments with this line. Move the triangle to the desired location and draw a new line CD. Point P indicates the location of the desired distance between the two lines.

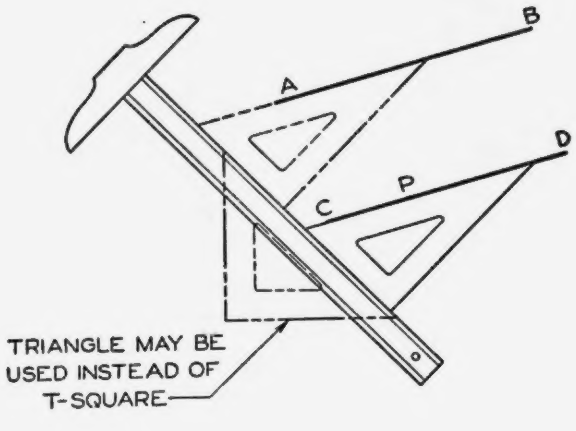

B
A
D
P
C
TRIANGLE MAY BE USED INSTEAD OF T-SQUARE

Figure 8. Drawing Parallel Lines.

To Divide a Straight Line into Any Number of Equal Parts

Draw a vertical construction line at one end of a given line. Set the zero of your scale at the other end of the line. Swing the scale up until the desired unit falls on the vertical line, and make tiny dots at each point. Draw vertical construction lines through each point.

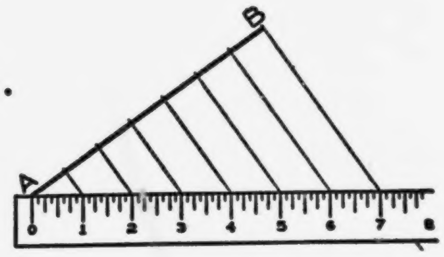

B
A
0
1
2
3
4
5
6
7
8

Figure 9.

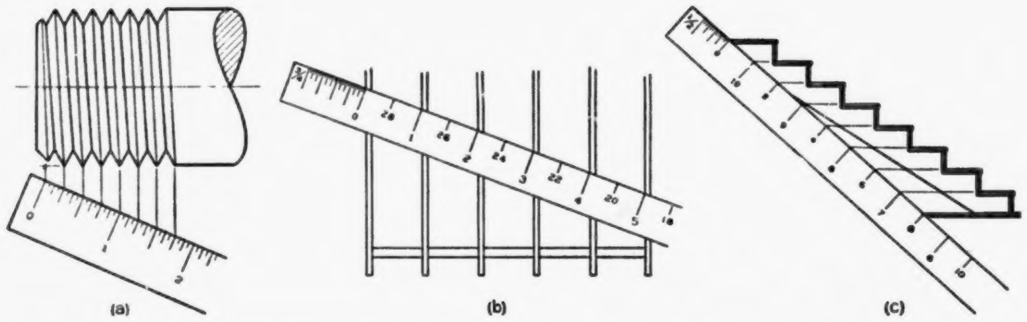


Figure 10. **Practical Applications of Dividing a Line into Equal Parts**

To Draw a Circle Tangent to a Line at a Given Point

Given line AB and a point P on the line as shown at (a), at P, erect a perpendicular to the line. Set off the radius of the required circle on the perpendicular. Draw a circle with radius CP.

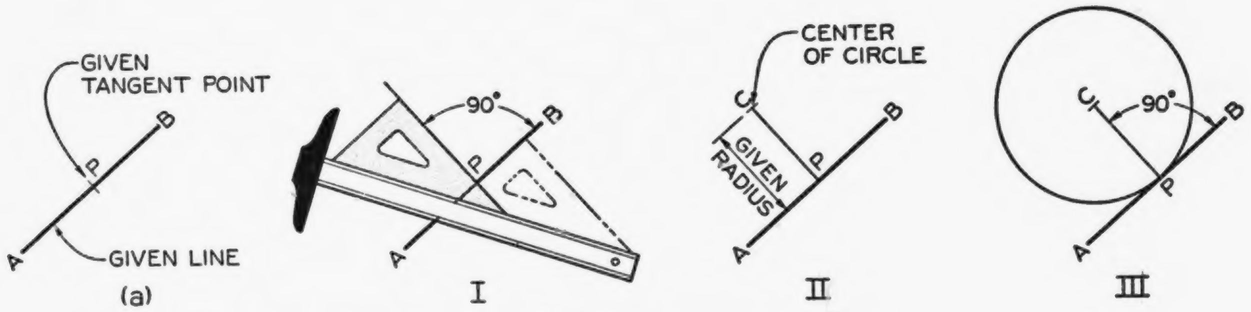

GIVEN TANGENT POINT
B
P
A
GIVEN LINE
(a)
90°
B
P
A
I
CENTER OF CIRCLE
C
B
P
GIVEN RADIUS
A
II
C
90°
B
P
A
III

Figure 11. **Drawing a Circle Tangent to a Line**

To Draw a Tangent to a Circle through a Point

Given point P on the circle, move the T-square and triangle as a unit until one side of the triangle passes through the point P and the center of the circle. Then slide the triangle until the other side passes through point P, and draw the required tangent.

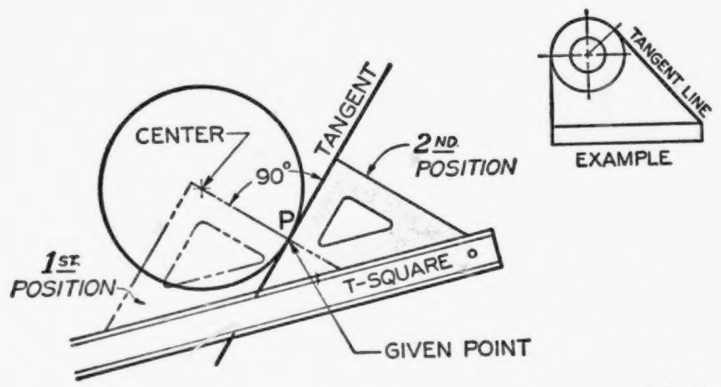

TANGENT LINE
EXAMPLE
CENTER
90°
TANGENT
2ND POSITION
P
1ST POSITION
T-SQUARE
GIVEN POINT

Figure 12.

Drawing a Tangent to a Circle through a Point

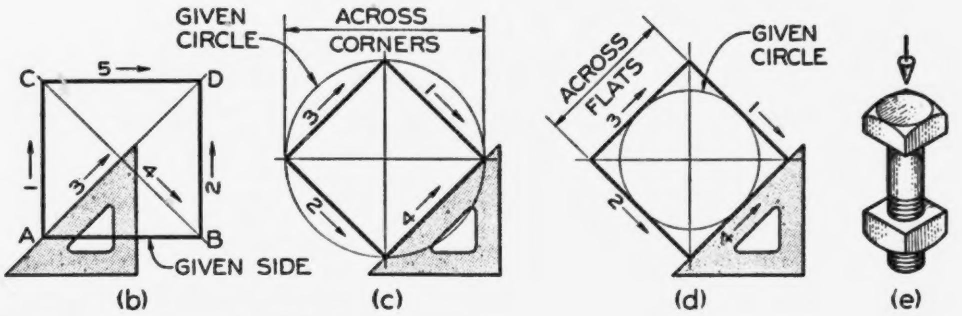
To Draw a Square

Given one side AB using the T-square and 45° triangle, draw lines AC and BD perpendicular to AB and the lines AD and BC at 45° with AB. Draw line CD with the T-square.

Figure 13(c). Given the circumscribed circle (distance "across corners"), draw two diameters at right angles to each other. The intersections of these diameters with the circle are vertexes of an inscribed square.

Figure 13(d). Given the inscribed circle (distance "across flats", as in drawing bolt heads) and using the T-square and 45° triangle, draw the four sides tangent to the circle.

Figure 13.


GIVEN CIRCLE
ACROSS CORNERS
C
5
D
3
4
2
1
A
B
GIVEN SIDE
ACROSS FLATS
GIVEN CIRCLE
(b)
(c)
(d)
(e)

Drawing a Square

To Draw a Regular Pentagon

I. Bisect radius OD at C.

II. With C as center and CA as radius, strike arc AE. With A as center and AE as radius, strike arc EB.

III. Draw line AB. Set off distances AB around the circumference of the circle and draw the sides through these points.

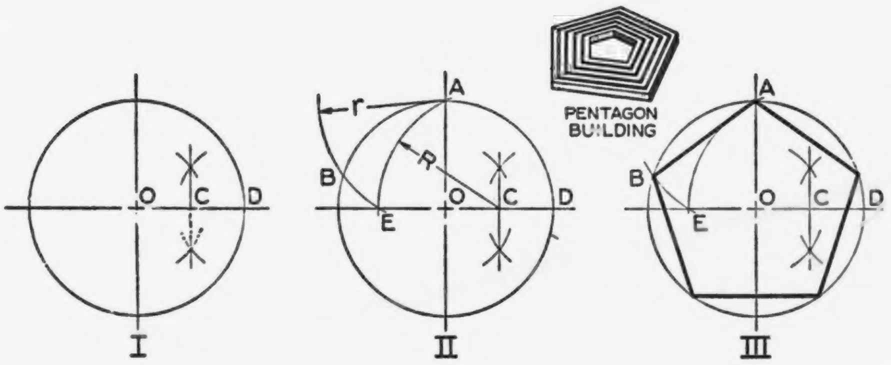

O
C
D
I
r
A
B
R
E
O
C
D
II
PENTAGON BUILDING
A
B
E
O
C
D
III

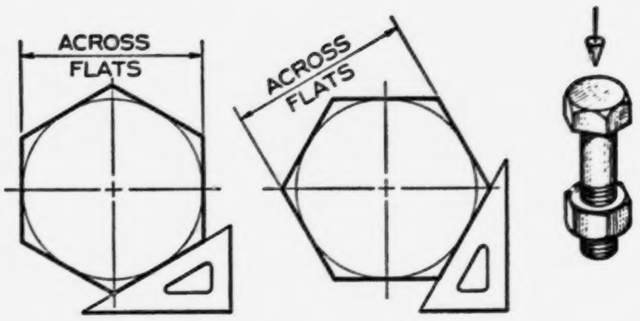
Figure 14.

Drawing a Pentagon

To Draw a Hexagon

Given the inscribed circle (distance "across flats"), draw vertical and horizontal center lines. With the 30°-60° triangle and T-square, draw the six side tangent to the circle. This method is used in drawing bolt heads and nuts.

Figure 15.
Drawing a Hexagon



To Draw an Octagon

Given the inscribed circle (distance "across flats") and using the T-square and 45° triangle, draw the eight sides tangent to the circle as shown.

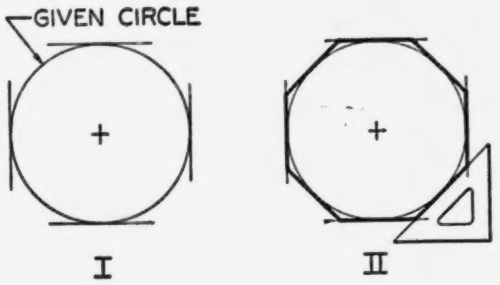


Figure 16.

To Draw Concentric-Circle Ellipse

If a circle is viewed "head on" so that the line of sight is perpendicular to the plane of the circle as shown for the silver dollar at (a), the circle will appear as a circle in true size and shape. If the circle is viewed at an angle as shown at (b), it will appear as an ellipse. If the circle is viewed edgewise, it appears as a straight line as shown at (c). The case shown at (b) is the basis for the construction of an ellipse by the CONCENTRIC-CIRCLE METHOD as follows. (Keep construction very light.)

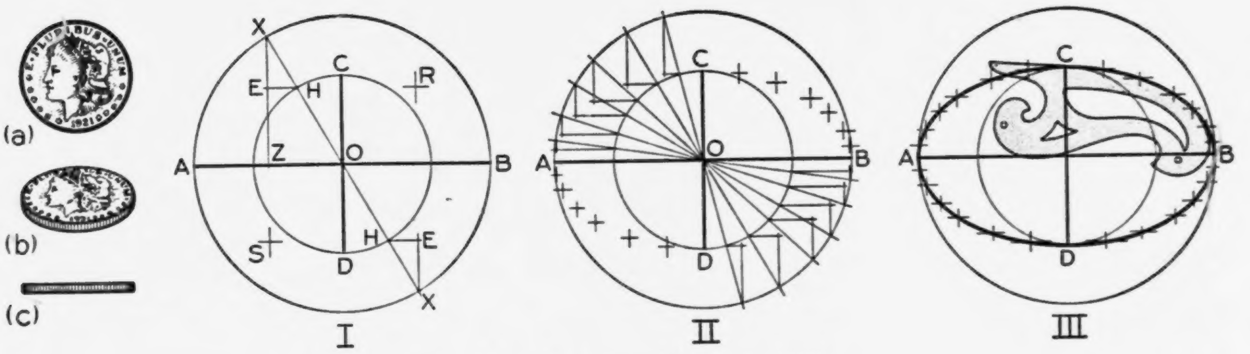


Figure 17. Drawing Concentric-Circle Ellipse

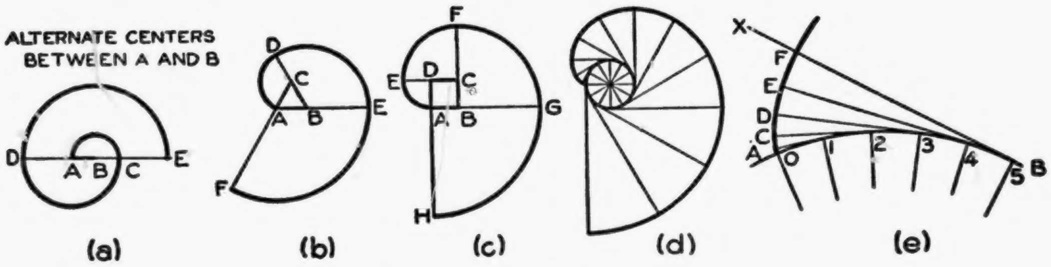
I. Draw circles on the two axes as diameters and draw any diagonal XX through center O. From the points X in which the diagonal intersects the large circle, draw lines XE parallel to the minor axis; and from points H in which it intersects the small circle, draw lines HE parallel to the major axis. The intersections E are points on the ellipse. Two additional points, S and R, can be found by extending lines XE and HE, giving a total of four points from the one diagonal XX.

II. Draw as many additional diagonals as needed to provide a sufficient number of points for a smooth and symmetrical ellipse, each diagonal accounting for four points on the ellipse. Notice that where the curve is sharpest (near the ends of the ellipse), the points are constructed closer together to better determine the curve.

III. Sketch the ellipse lightly through the points. Then draw in the final ellipse with the aid of the irregular curve.

To Draw an Involute

The path of a point on a string as the string unwinds from a line, polygon, or circle, is an INVOLUTE.



Involutes

Figure 18.

Figure 18a. To draw an involute of a line. Let AB be the given line. With AB as radius and B as center, draw the semicircle AC. With AC as radius and A as center, draw the semicircle CD. With BD as radius and B as center, draw the semicircle DE. Continue similarly, alternating centers between A and B until a figure of the required size is completed.

Figure 18b. To draw an involute of a triangle. Let ABC be the given triangle. With CA as radius and C as center, strike arc AD. With BD as radius and B as center, strike arc DE. With AE as radius and A as center, strike arc EF. Continue similarly until a figure of the required size is completed.

Figure 18c. To draw an involute of a square. Let ABCD be the given square. With DA as radius and D as center, draw the 90° arc AE. Proceed as for the involute of a triangle until the required figure is completed.

Figure 18d. To draw an involute of a circle. A circle may be regarded as a polygon with an infinite number of sides. The involute

is constructed by dividing the circumference into a number of equal parts, drawing a tangent at each division point, setting off along each tangent the length of the corresponding circular arc, and drawing the required curve through the points set off on the several tangents.

Figure 18e. The involute may be generated by a point on a straight line which is rolled on a fixed circle. Points on the required curve may be determined by setting off equal distances 0-1, 1-2, 2-3, etc., along the circumference, drawing a tangent at each division point, and proceeding as explained for 18d.

The involute of a circle is used in the construction of involute gear teeth.

ASSIGNMENT:

Using size "B" drawing paper and simplified title block, divide the drawing area into six areas. Divide the vertical distance into two parts and the horizontal distances into three equal divisions.

In each space, do one of the following problems in geometric construction. Complete all six problems and title the entire drawing "Geometric Constructions." You may abbreviate the title if necessary.

1. Draw a line three inches long at 30° to the page. Bisect with a compass. Label the ends "A" and "B" and the perpendicular "C" and "D".

2. Draw a horizontal line, AB, $3\frac{5}{8}$" long and subdivide into eight equal parts.

3. Draw two lines $3\frac{1}{2}$" long intersecting at 45°. Bisect the angle with the compass.

4. Draw a circle $3\frac{1}{2}$" in diameter. Inscribe a pentagon.

5. Draw a hexagon three inches across its "flats."

6. Draw an ellipse having a major axis of $3\frac{1}{4}$" and a minor axis of $1\frac{3}{4}$". (Borrow a french curve from your instructor.)

UNIT III - MULTIVIEW SKETCHING AND PROJECTION

Technical Sketching — Lesson 1

OBJECTIVES:

1. To relate the basic principles of sketching.
2. To relate the importance of technical sketching as it applies to the effective visualization of objects.
3. To relate an understanding of pencil technique and line weights and the importance of neatness and accuracy in sketching.
4. To relate guide line establishment in connection with three-view sketching.
5. To parallel this information with the classroom instruction found in Lesson 2 relating to multiview drawing.

REFERENCES:

1. Chapter 5, TECHNICAL DRAWING, Giesecke, Mitchell, and Spencer.
2. Chapter 6, MECHANICAL DRAWING, French and Svensen.

INFORMATION:

The importance of the ability to produce good freehand sketches cannot be overestimated. Sketching enables the individual to relate his ideas to another person more quickly than by the use of drawing instruments.

Most original mechanical ideas are first drawn in the form of sketches. All preliminary work leading to the production of working drawings must be done through the medium of sketches.

It is therefore important that the drafting student take time to develop an accuracy of observation, a good sense of proportion, and a sureness of handling the drawing pencil through the production of sketches.

Not only can sketches be applied to the understanding of parts and details in developing new ideas, but also to the explaining of applications of parts already drawn.

As you undertake the exercises outlined for this unit, be sure to use good line quality. Quality of lines indicates that they are consistently "black", being made without excessive pressure on the pencil. Good lines provide contrast which makes a drawing easy to read.

For sketching purposes, choose a pencil having a relatively soft grade of lead. Most common household pencils serve the purpose nicely.

Arrangement of Views

Lesson 2 deals in detail with the methods of selecting and arranging multiview drawings of objects. For the purposes of this lesson, a three-view drawing involving the front, top, and right-side projections of each object will be used.

When considering any object in its entirety, there are six possible views (see figure 1). In most cases, objects can be adequately described by using any three views. Standardly, the front, top, and right side are selected unless invisible detail or lack of adequate shape description requires other views to be utilized.

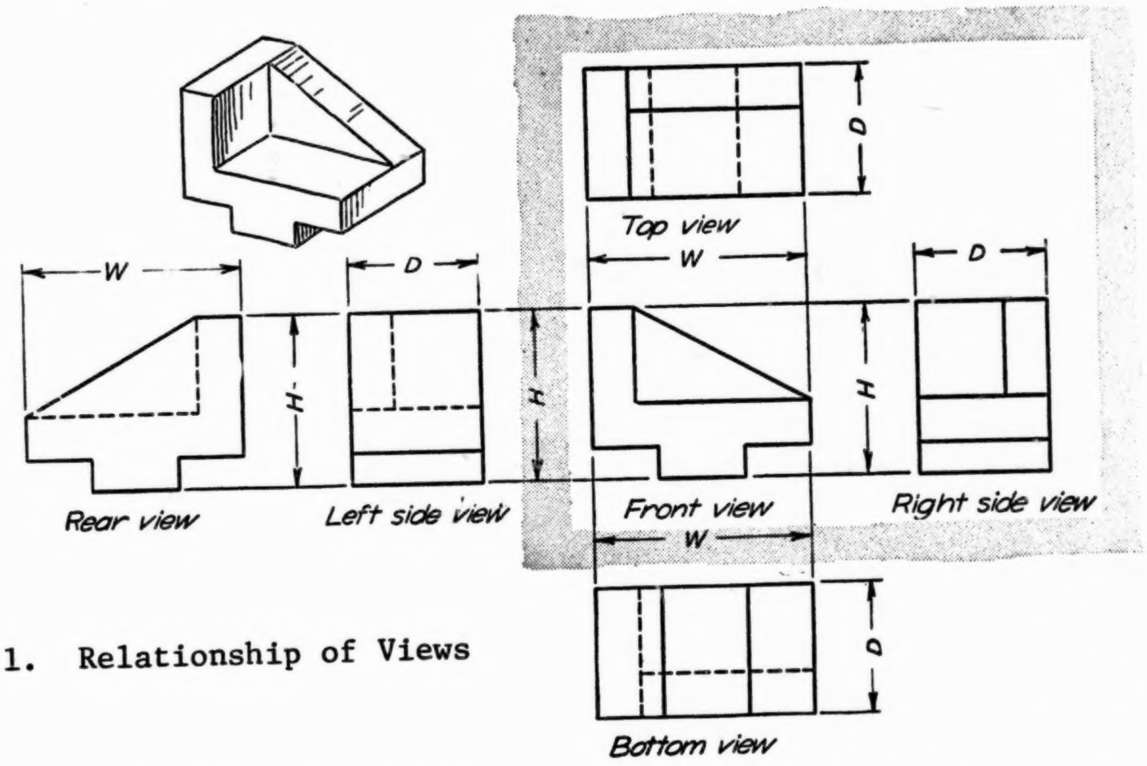


Figure 1. Relationship of Views

Relationship of Views to Objects

When sketching objects, sizes and distances proportionate to the actual object should be related on your drawing. For example, if an object is 3" long and 2" wide, the sketch should appear approximately two-thirds as wide as it is in length.

When drawing or sketching (figure 1), the width (W) and the height (H) are generally related in the front view. Projecting upward, the top view exposes the depth (D) in reference to the width. Projecting to the right, the right side view combines the depth (D) with the height (H). The lines between the views showing the direction of projection in actual drawing practice are only guide lines and are not prominent in the finished sketch.

Notice that the heavy solid lines in each view relate directly to the edges of the object visible from that particular direction. These are called OBJECT LINES. Surfaces and edges which are hidden from direct view (top view), such as the key on the bottom of this object, are represented by broken lines. These are known as HIDDEN LINES.

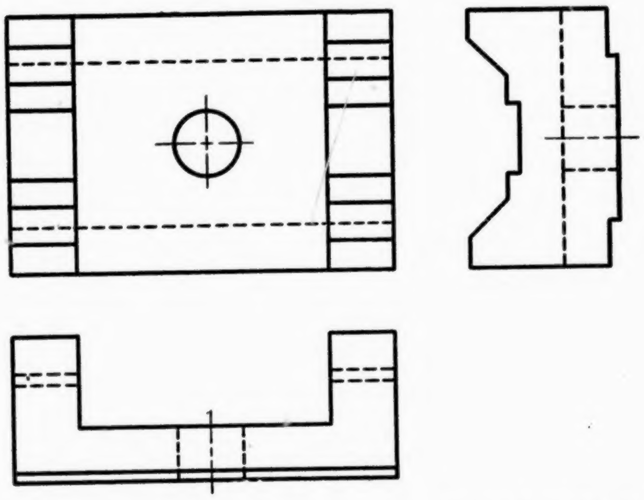
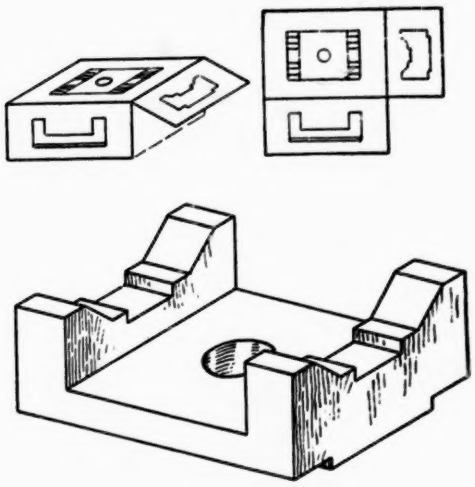


Figure 2.



Second position of the side view.

In almost all drawings, the right side view will be projected adjacent to the front view. One exception to this rule occurs, however, when the depth of the object is greater than the height(figure 2). In this case, the right side view is placed adjacent to the top view to more closely relate the view and to conserve drawing space on the page. In general, the longest edges shown in all views of an object should be more closely related. The importance of this practice will be better seen when dimensioning procedures are explained in a later lesson.

Making a Sketch

When making a sketch of an object, you must observe the object carefully to determine which views are necessary to adequately describe all surfaces and edges.

Be sure that a view is present which describes those features which appear as hidden lines in other views. (See figure 4(5).) In this situation, the right side view exposes the corner cut-out which is shown as a hidden line in both the front and top views.

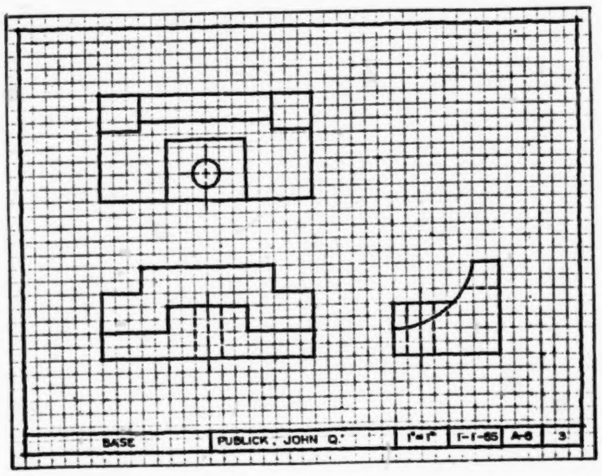
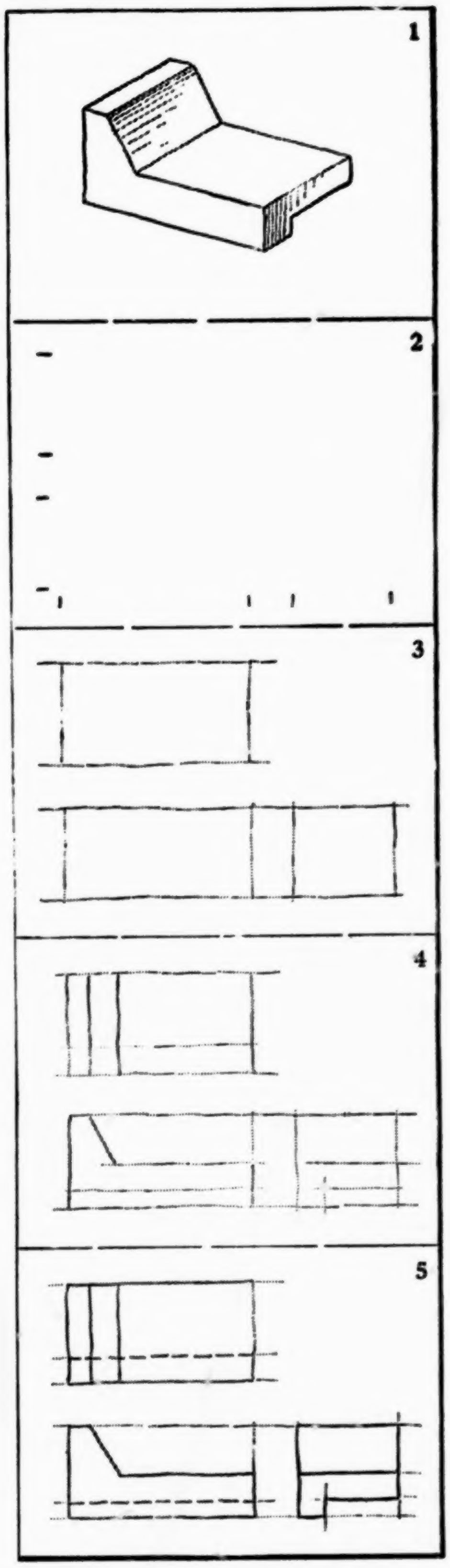


Figure 3. A three-view sketch.



When starting the sketch, consider carefully the proportions of the object (figure 4(1)). Estimate the proportions carefully and mark off distances for the three views as in figure 4(2). Block in the enclosing rectangles as in figure 4(3). Locate the details in each of the views and block them in as in figure 4(4). Finish the sketch by brightening the lines as in figure 4(5). The preliminary guide lines should be made as light as possible so that they will not have to be erased and so that dashes for hidden lines can be drawn over them.

In most of your sketching practice you will be working from pictorial views similar to those incorporated with figures 1 - 3. The three surfaces shown in the view should, for the present time, be considered as the views you will represent in your sketches. The insert above the pictorial view in figure 2 demonstrates how the three views are related. Remember that the first choice of right side view positioning is adjacent to the front view.

Figure 4. Stages of Making a Sketch

Pictorial Sketching

Pictorial sketches often provide a way of checking the understanding of a drawing and, in many cases, constitute the entire drawing of an object.

Since you will at many times in your drawing experience find it necessary to "picture" objects for yourself or others and also to develop your own understanding of view relationships, pictorial drawing is considered here. (See Unit VI also.)

There are many types of pictorial drawing including oblique, dimetric, trimetric, cavalier, perspective, and isometric. For ease of construction, isometric drawing is most often used to provide quick sketches of objects.

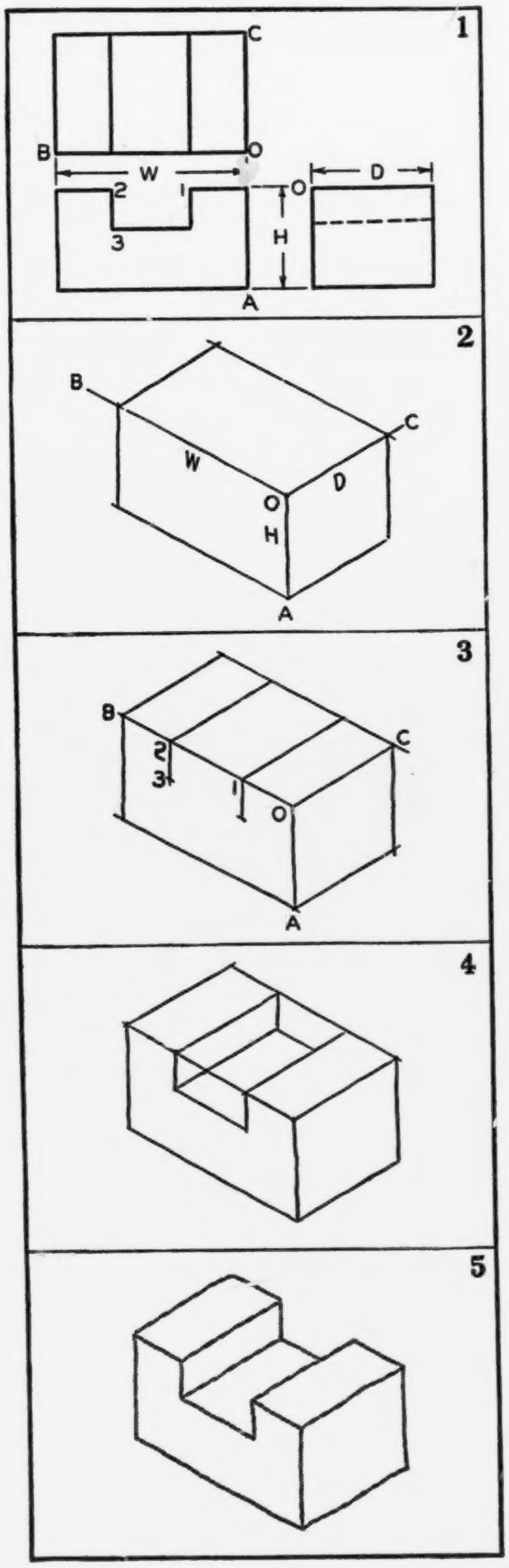
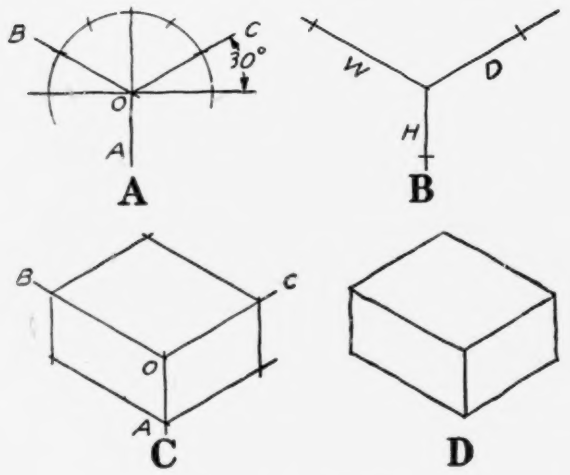


Figure 5. Stages in making an isometric sketch.

Isometric Drawing

Isometric sketching is based on three lines called axes which are used to give direction to the height (H), width (W), and depth (D) of an object (figure 5). The height is shown by a vertical line OA. The width, OB, and the depth, OC, are shown by making lines 30° from horizontal. Estimate the angle as one-third of a right angle as shown in figure 6.



Axes for pictorial sketches.

Figure 6.

Making the Sketch

Following the steps shown in figure 5, first sketch the three axes as shown in space 2. Referring to the three-view sketch (orthograthic drawing), estimate the proportions of the object and place in the height on all three axes. Traveling back from points B and C, enclose the entire prism thus limiting the view area. Areas to be "cut out" of the blocked-in area are placed in by forming lines on the proper face of the object as with lines 1 and 2 in space 4. Connecting lines to the rear of the object, in this case, complete the cut-out. Brightening the object lines completes the sketch, space 5.

All objects should be enclosed in a box during your sketching practice. Note, however, that the objects shown in figure 7 have some lines that are not PARALLEL to the axes. In such cases, locate the ends of the lines and join them. Sets of lines that are parallel on the object will show as parallel on your sketches even though they are not parallel to one of the axes.

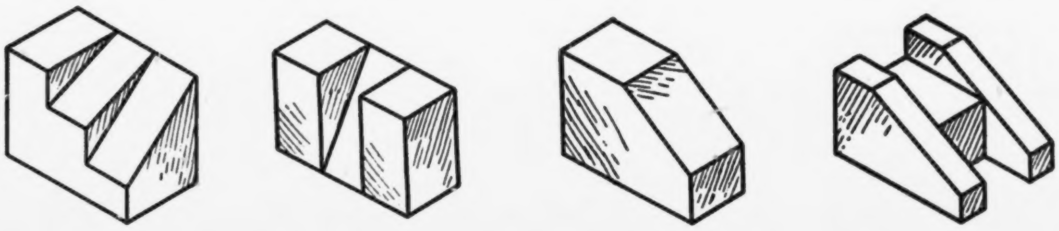


Figure 7. Isometric Sketches

Circles and Arcs

On isometric sketches, circles and arcs will appear elliptical in form (figure 17, page 53). You must draw a circumscribing square (figure 8) on the proper plane and sketch the ellipse in it. Note that center guide lines are used with the square.

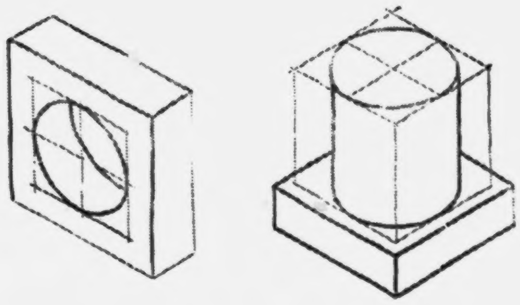
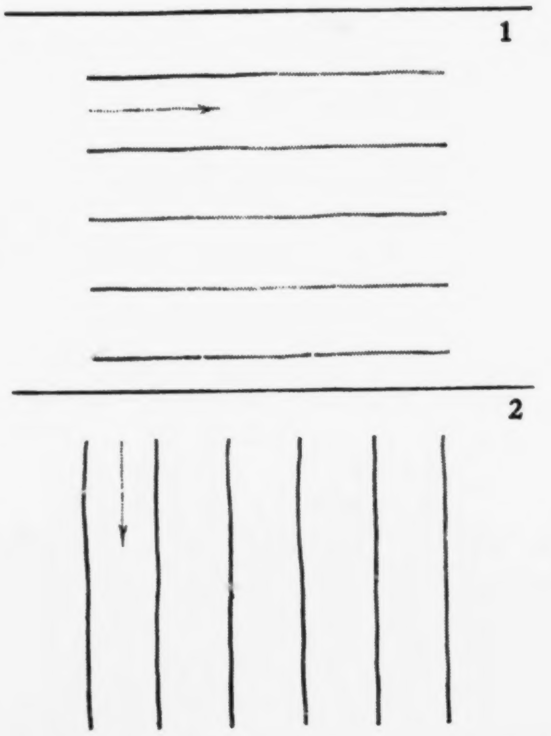


Figure 8. Circles and Arcs

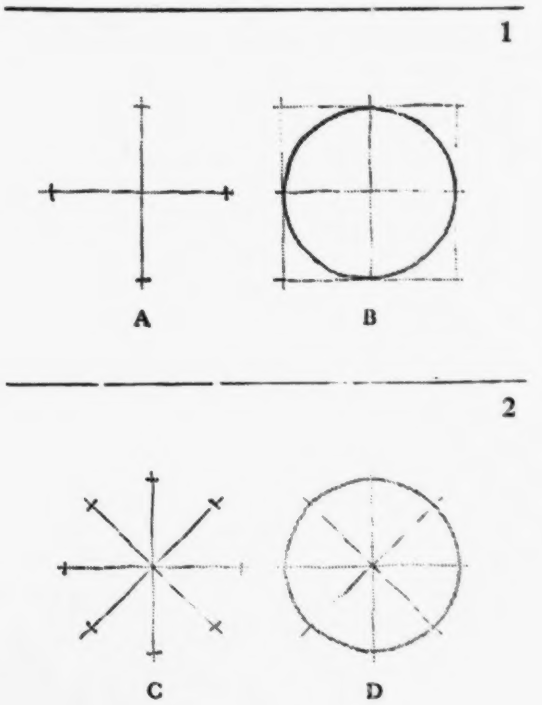
ASSIGNMENT:

Problems 1 & 2 are chosen to develop good sketching habits. Hold the paper in a convenient position and sketch all lines in the direction indicated by the arrows.

Do your sketching work on plain white paper (typing or similar bond) folded into eight sections, four vertically and two horizontally. Do both series of four exercises on the one sheet. Sketch the lines quickly in each case using one continuous rapid stroke for each line. In this way you will develop a "feel" of the pencil and the ability to make sketches quickly and accurately.



Problem 1.



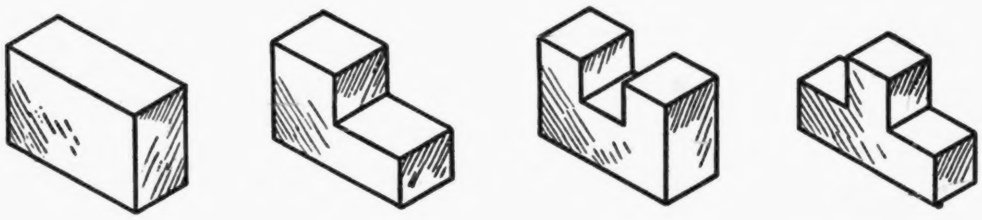
Problem 2.

Problem 3. Using quadrille paper, hold the paper vertically and fold the paper down forming two sections. Two sketches will be made on each side of the paper. Total four per page.

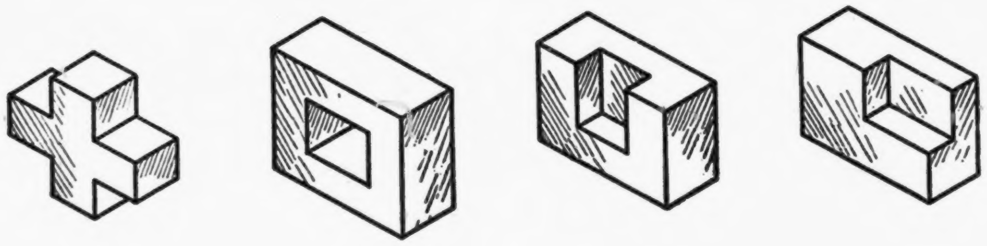
Note. Some sketches may be assigned as class work. Pay attention to the instructor's directions.

Make three-view sketches for all problems in each series below, one complete series to each page of your work. For series 7, 8, 9, and 10, draw the pictorial sketch of the object with the three orthographic views. Follow the outline given for pictorial sketching. Title each as series "1", series "2", etc. Draw each object as having a width of between 3" to $3\frac{1}{2}$".

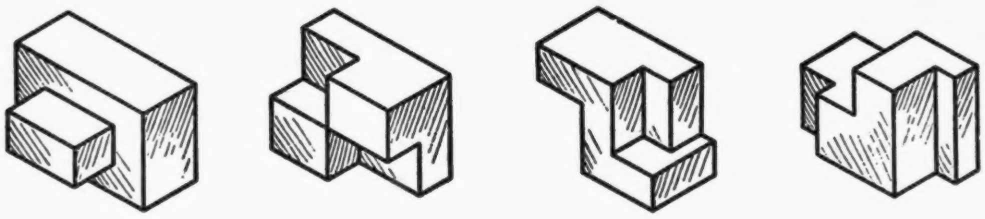
PROBLEM 3.



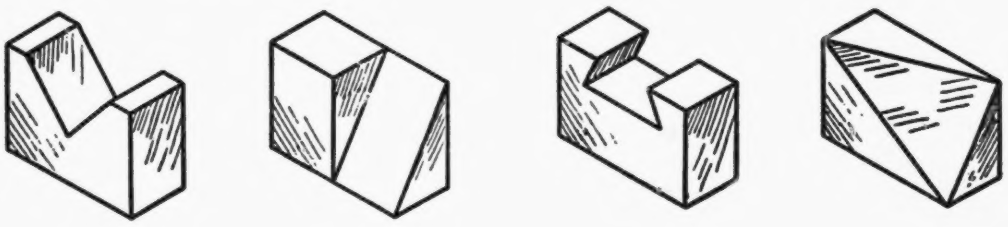
Series 1.



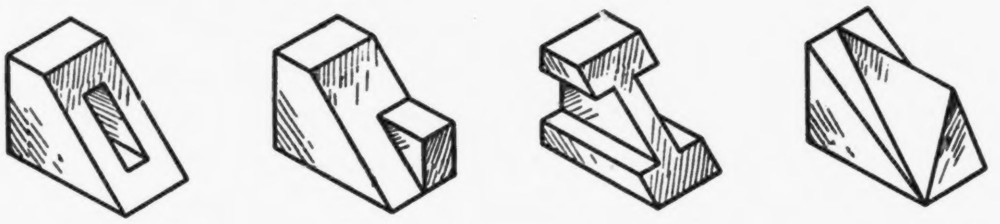
Series 2.



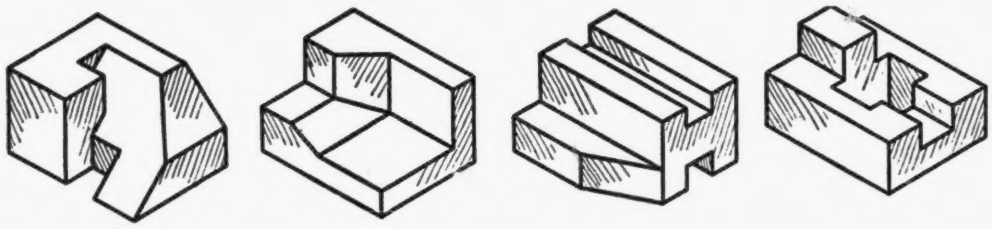
Series 3.



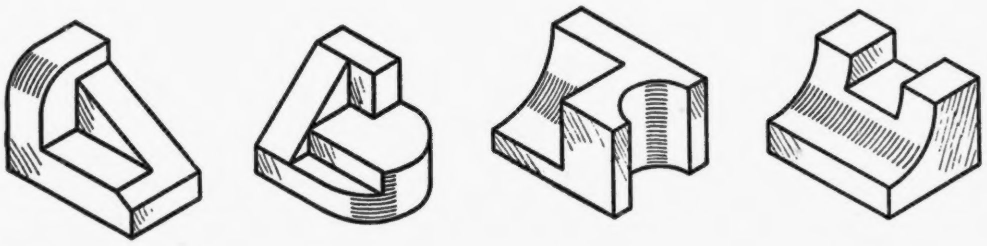
Series 4.



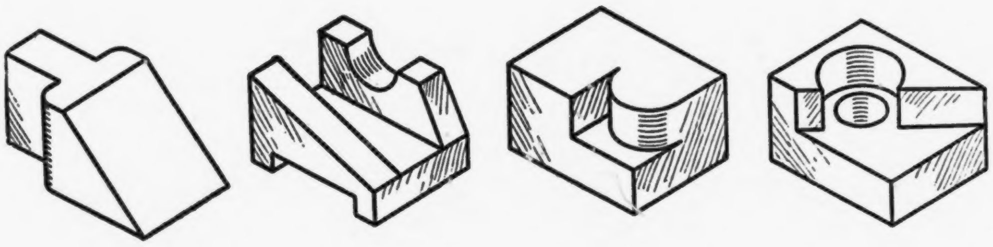
Series 5.



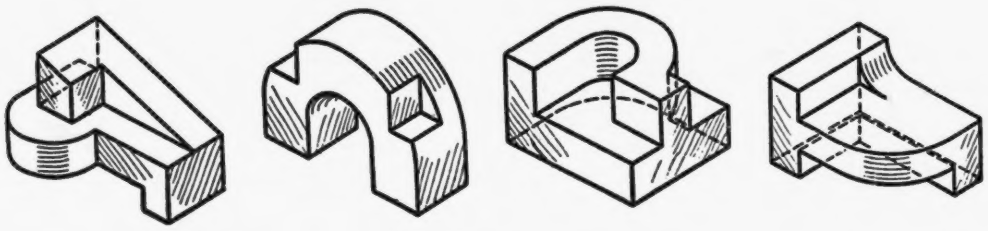
Series 6.



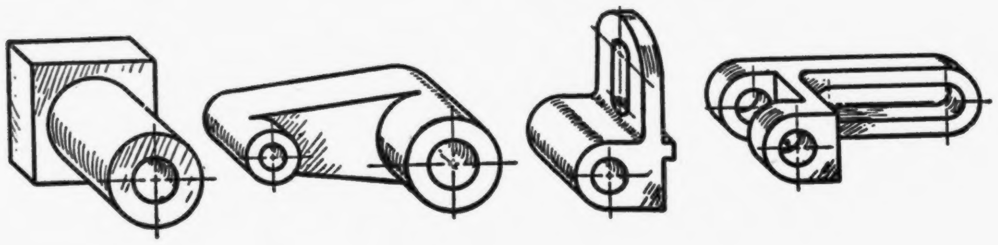
Series 7.



Series 8.



Series 9.



Series 10.

UNIT III - MULTIVIEW SKETCHING AND PROJECTION

Orthographic Projection

Lesson 2

OBJECTIVES:

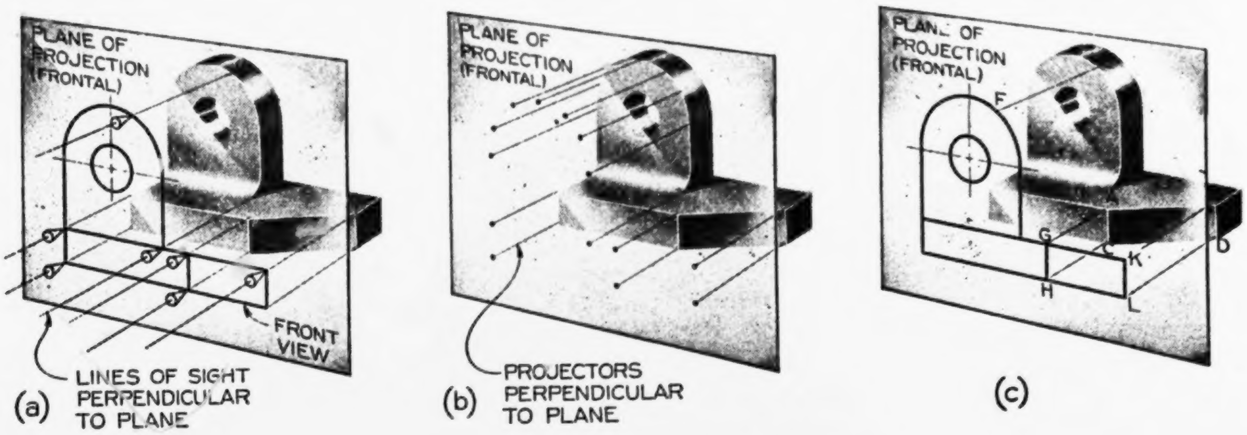
1. To relate this unit with the work done in lesson 1.
2. To explain "projection" of views.
3. To relate instrument drawing techniques for making orthographic drawings.
4. To explain techniques of hidden line structure.

REFERENCE:

1. Chapters 5 and 6, TECHNICAL DRAWING, Giesecke, Mitchell, and Spencer.

INFORMATION:

A view of an object is technically known as a projection. A projection is a view conceived to be drawn or "projected" onto a "plane of projection." The view is obtained by drawing perpendiculars called "projectors" from all points on the edges or contours of the object to the plane of projection.

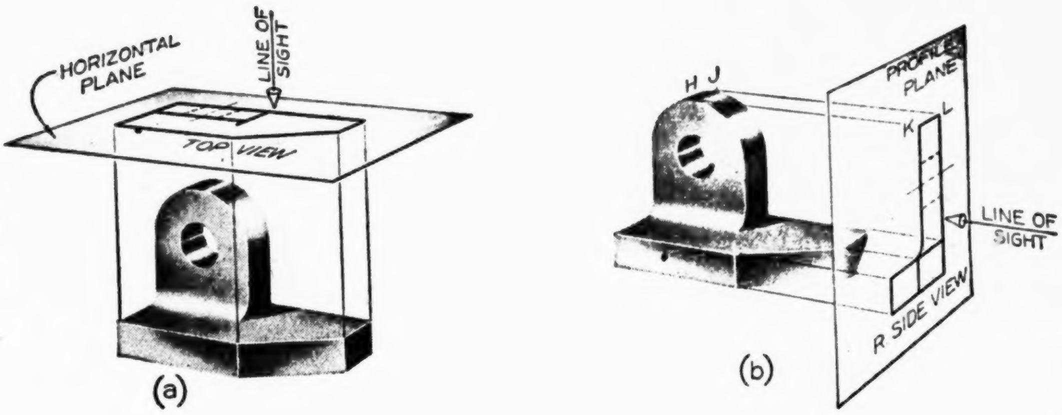

PLANE OF PROJECTION (FRONTAL)
FRONT VIEW
LINES OF SIGHT PERPENDICULAR TO PLANE
(a)
PLANE OF PROJECTION (FRONTAL)
PROJECTORS PERPENDICULAR TO PLANE
(b)
PLANE OF PROJECTION (FRONTAL)
F
G
C
K
D
H
L
(c)

Projection of an Object.

Figure 1.

If the observer is considered to be located at infinity, the projectors will be parallel; and if in addition to being parallel the projectors are perpendicular to the plane of projection, the result is an "orthographic projection." The term ORTHOGRAPHIC means"to write or draw at right angles."

Figure 2.


HORIZONTAL PLANE
LINE OF SIGHT
TOP VIEW
(a)
H J
PROFILE PLANE
K L
LINE OF SIGHT
R SIDE VIEW
(b)

Projecting top and right side views.

Selection of Views

It is possible to view an object from six mutually perpendicular directions. The views, according to the American Standard method, are arranged directly in line with each other both horizontally and vertically as shown in figure 3(b).

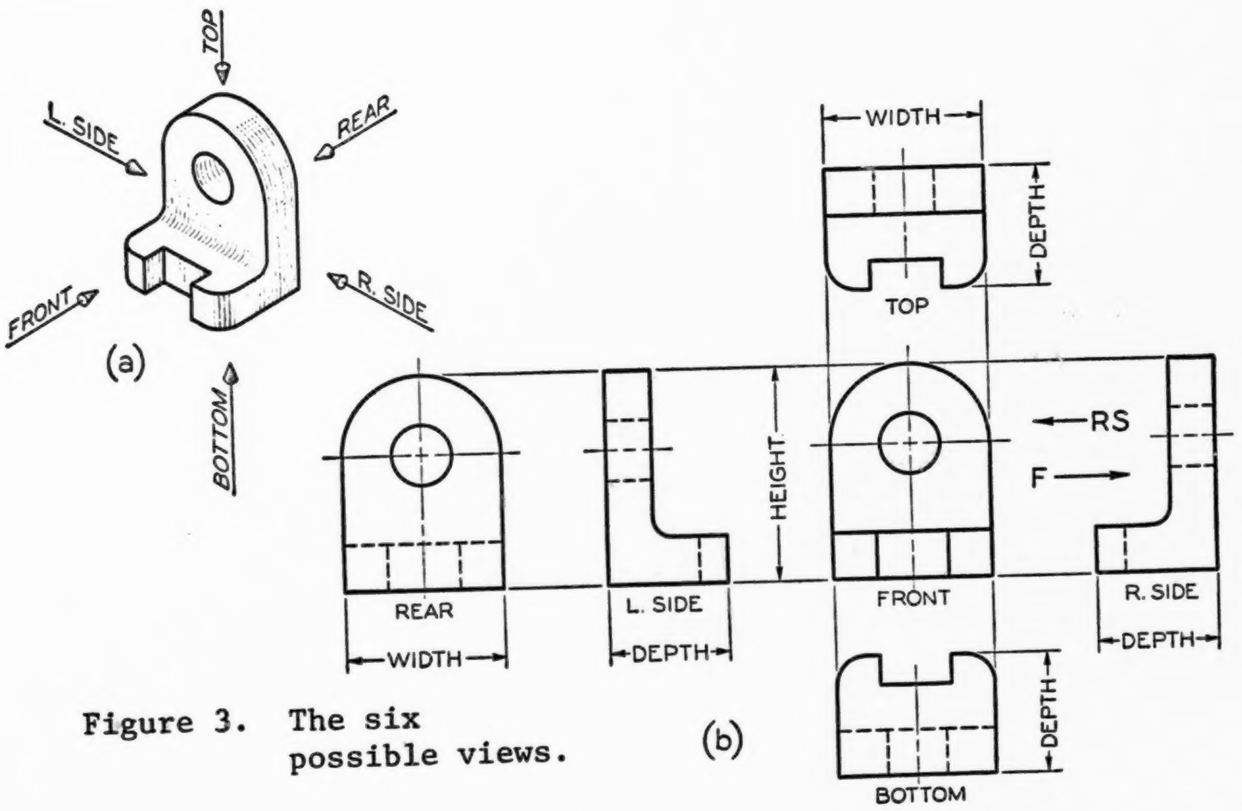

TOP
L. SIDE
REAR
FRONT
R. SIDE
BOTTOM
(a)
WIDTH
DEPTH
TOP
RS
F
HEIGHT
REAR
L. SIDE
FRONT
R. SIDE
WIDTH
DEPTH
DEPTH
DEPTH
BOTTOM
(b)

Figure 3. The six possible views.

Any one view of an object will only describe two dimensions of the object. The third dimension is described in an adjacent view. Therefore, more than one view of an object is necessary to describe a three-dimensional object completely.

Standardly, three views are selected in order to adequately describe an object. The three most used views are the FRONT, TOP, and RIGHT SIDE. These three views have become known as"the regular views" since they are utilized so often. The other three views are thus eliminated.

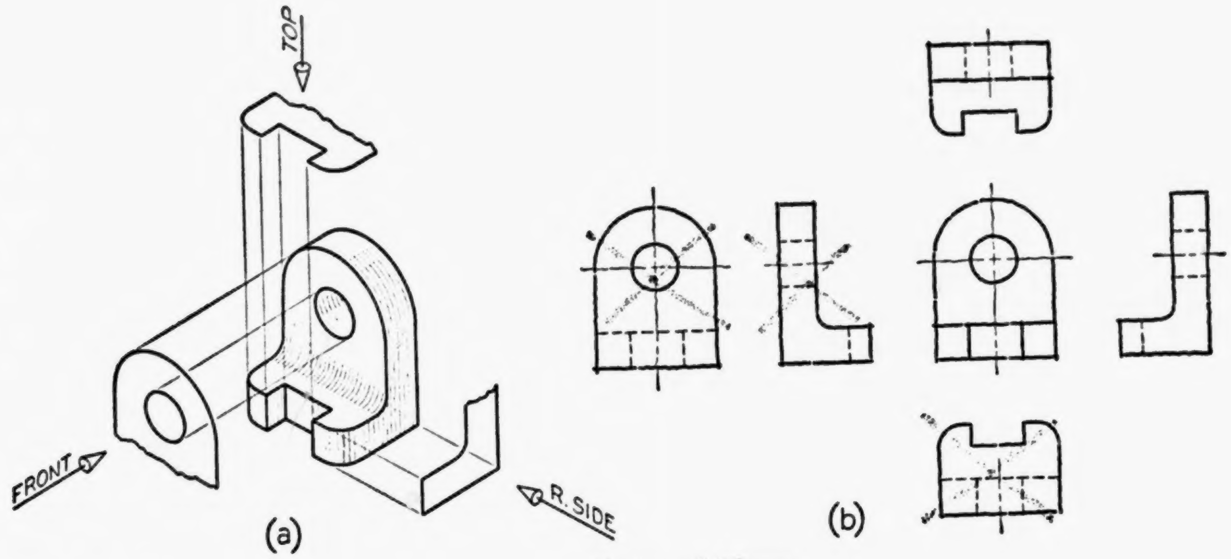
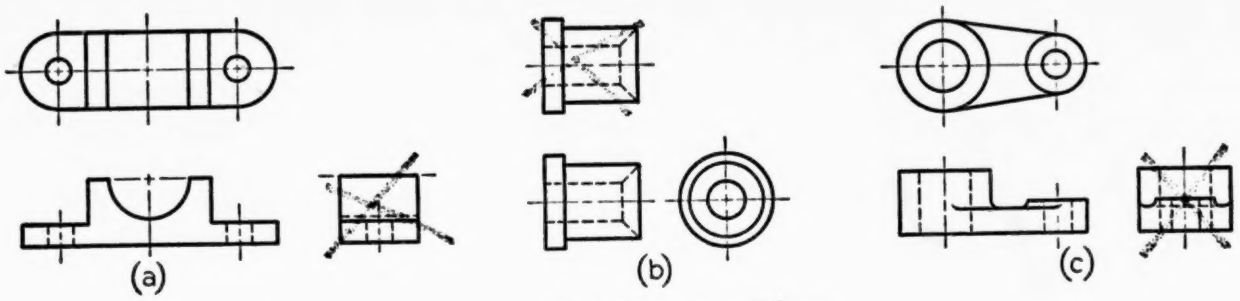


Figure 4. **Choice of Views.**

The draftsman should give preference to those views which adequately describe the distinctive features of the object when choosing them for a drawing. Selection of views which have the least number of hidden lines is also important. These views then become known as the NECESSARY VIEWS of the object. You will find in later experience that other views of objects may be alternately selected, replacing one or more of the "regular views."

Two-View Drawings

In learning to "visualize" objects, you may find in certain cases that three views of an object are not always necessary to provide adequate description.



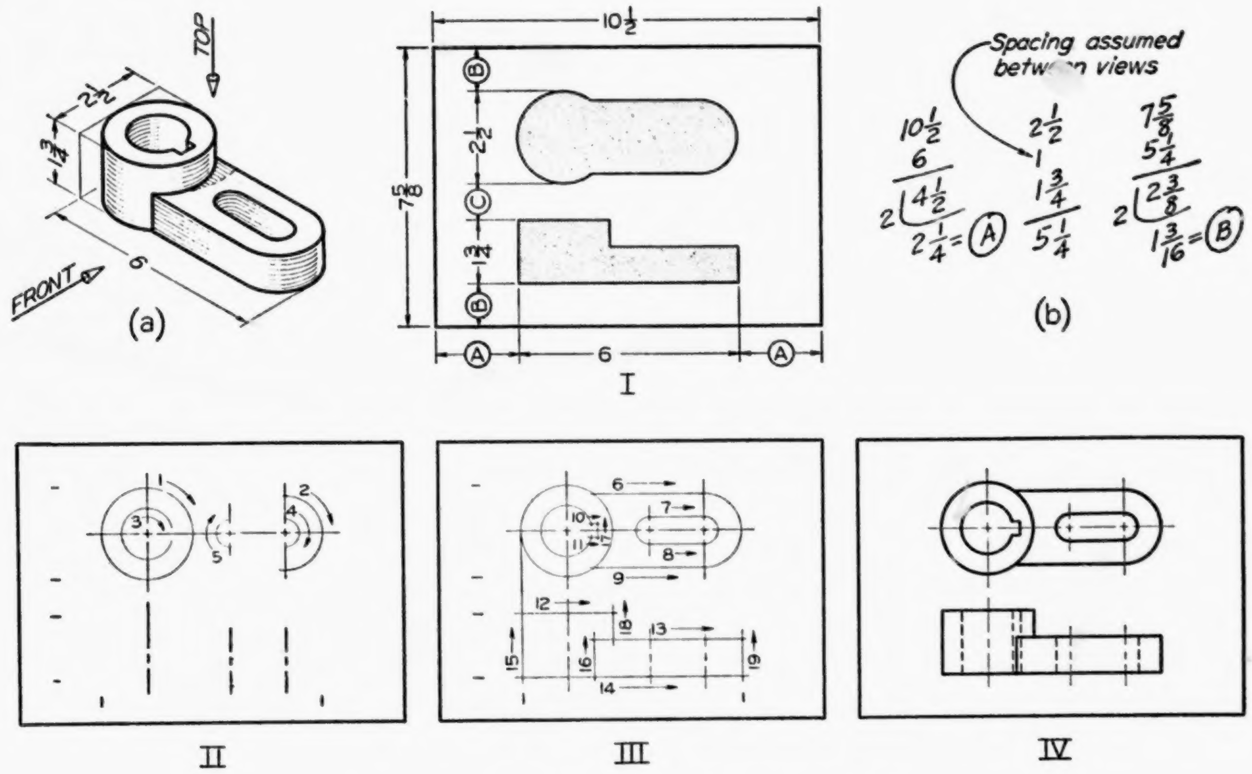
Two Necessary Views.

Figure 5.

When making two-view drawings, either the right side or the top view is eliminated. The eliminated view should be the one which provides the least information and would therefore not supplement the information afforded by the other two views.

Projection of Views

In instrument drawing, as with technical sketching, guide lines designating the overall size of the views must first be placed on the paper.


TOP
FRONT
$2\frac{1}{2}$
$1\frac{3}{4}$
$1\frac{1}{4}$
6
(a)
$10\frac{1}{2}$
$7\frac{5}{8}$
B
$2\frac{1}{2}$
C
$1\frac{3}{4}$
A
6
Spacing assumed betw…n views
$10\frac{1}{2}$
6
$2\overline{)4\frac{1}{2}}$
$2\frac{1}{4}$=A
$2\frac{1}{2}$
1
$1\frac{3}{4}$
$5\frac{1}{4}$
$7\frac{5}{8}$
$5\frac{1}{4}$
$2\overline{)2\frac{3}{8}}$
$1\frac{3}{16}$=B
(b)
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19

I

II

III

IV

Figure 6. Two-View Mechanical Drawing.

All drawing work must be neatly centered on the page both horizontally and vertically. Therefore, the amount of space required for the necessary views should be calculated and subtracted from the available space on the page. The remaining distances should be divided into two parts, appearing on both sides or to the top and the bottom of the drawing area. Consider the amount of space necessary between views to neatly balance your drawing. This space between views is calculated as part of the required drawing space and is considered, for the sake of centering, to be part of the view area.

Once the views are "blocked-in" using the drawing instruments in the prescribed manner, detail guide lines are drawn and finally all detail is darkened to proper object line quality.

Third View

When three-view drawings are made, the same centering procedure is followed as for two-view drawings, except that space must be provided for the right side view, allowing also a spacing distance between views.

All dimensions showing depth of the object in the top view should correspond point for point in the right side view. Methods of transferring depth dimensions are outlined in figure 8.

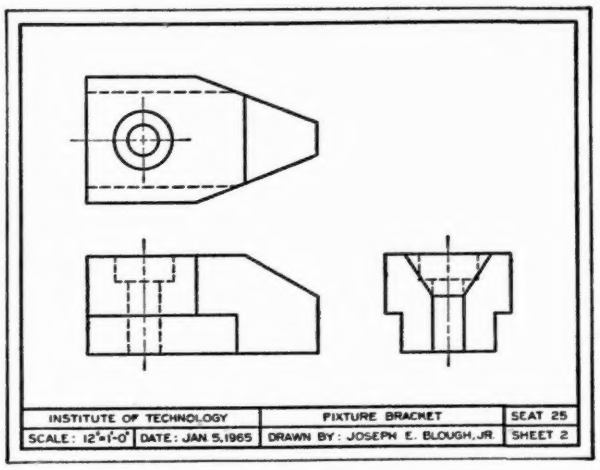
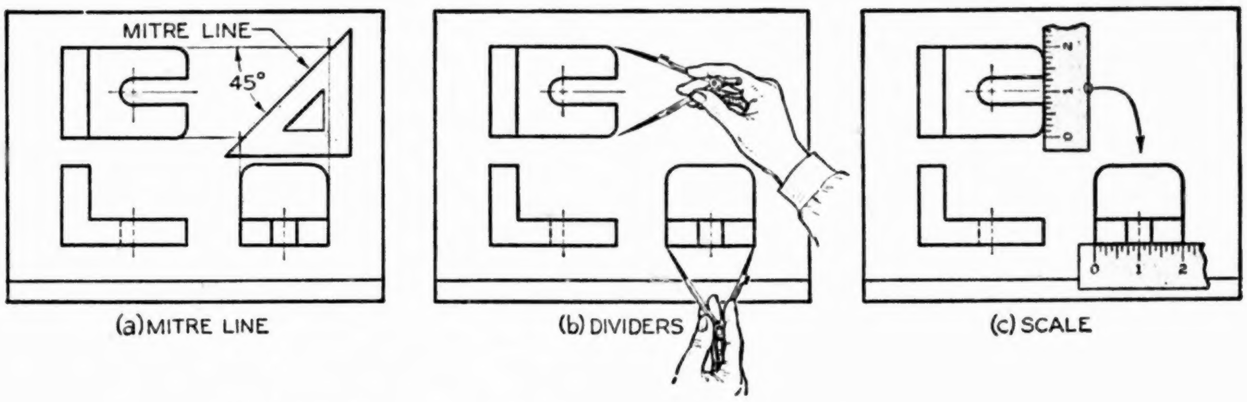

INSTITUTE OF TECHNOLOGY
FIXTURE BRACKET
SEAT 25
SCALE: 12"=1'-0"
DATE: JAN 5, 1965
DRAWN BY: JOSEPH E. BLOUGH, JR.
SHEET 2

Figure 7. A well-spaced three-view drawing.



(a) MITRE LINE (b) DIVIDERS (c) SCALE

Figure 8. **Transferring Depth Dimensions.**

Miter Line Projection

The easiest of the three methods and the most accurate for the beginning student is the "miter line" method of projection. This method requires the use of the 45^{o} triangle to transfer guide lines between the top and right side views.

This method eliminates the possibilities of inaccurate spacing which might occur through transfer of points by dividers or by repeated measuring with the scale. The other methods of transferring dimensions find application in other circumstances, especially where dimensions must be transferred from one drawing to another.

When learning to draw, however, it is preferred that you use the "miter line" method as outlined in figure 9 to project the right side view. Use your drawing instruments carefully, being sure that they do not "shift" from their proper positions while drawing.

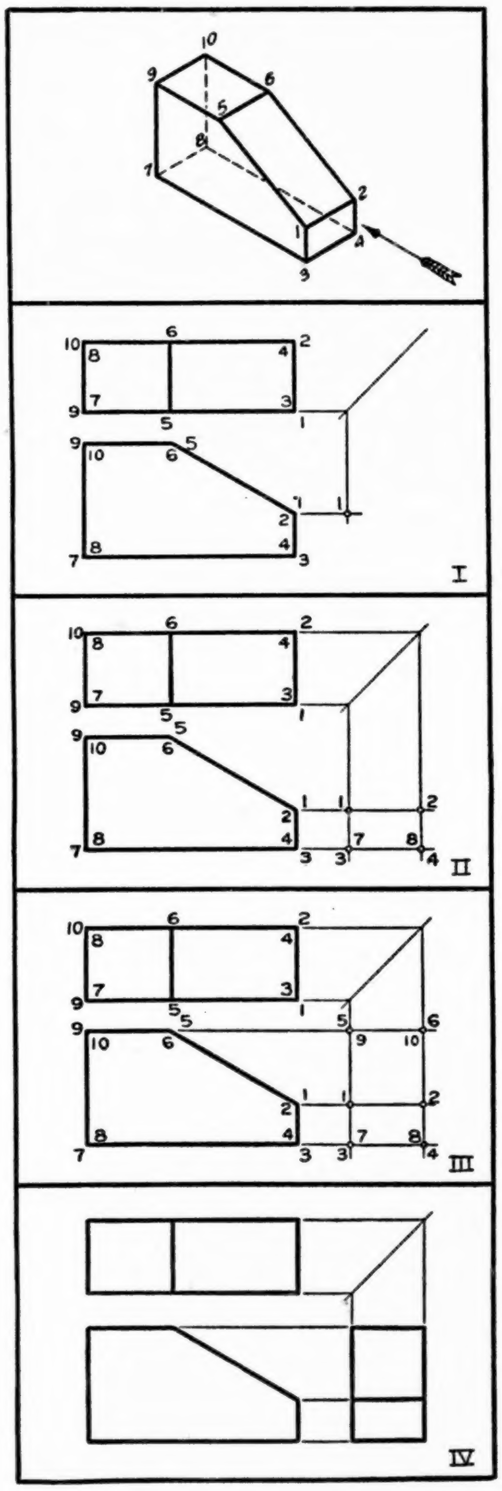
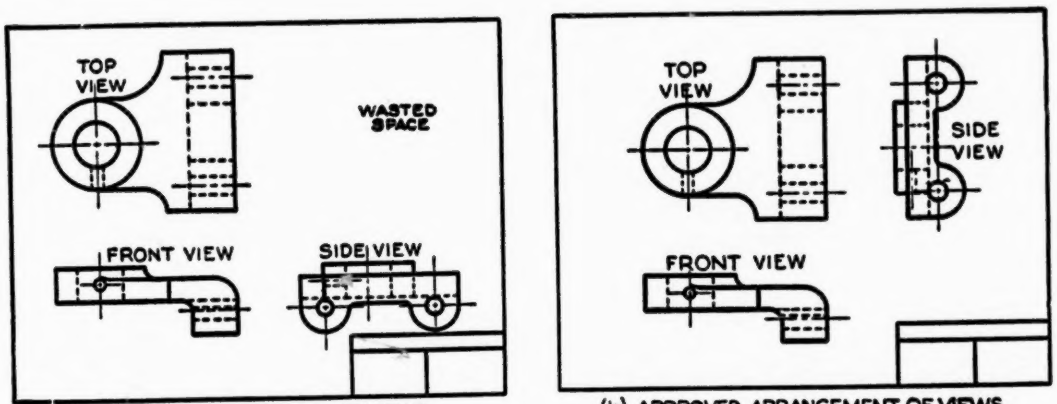


Figure 9. Miter line projection.

Alternate Position of Views


TOP VIEW
WASTED SPACE
FRONT VIEW
SIDE VIEW
TOP VIEW
SIDE VIEW
FRONT VIEW

(a) POOR ARRANGEMENT OF VIEWS

(b) APPROVED ARRANGEMENT OF VIEWS

Figure 10.

In cases where the depth of the object exceeds the height of the object, the right side view is placed adjacent to the top view to avoid the occurance of wasted space on the drawing. You can see in figure 10 that an improved drawing layout is achieved by this repositioning of the right side view. As a result, the drawing can be more easily "read." The "miter line" method of view projection would then apply between the front view and the right side view.

Hidden Lines

There are certain considerations to be noticed in the placement and formation of hidden lines on drawings. First of all, hidden lines are not quite as heavy as object lines, but are just as black. Secondly, the breaks along the line should be carefully measured and placed.

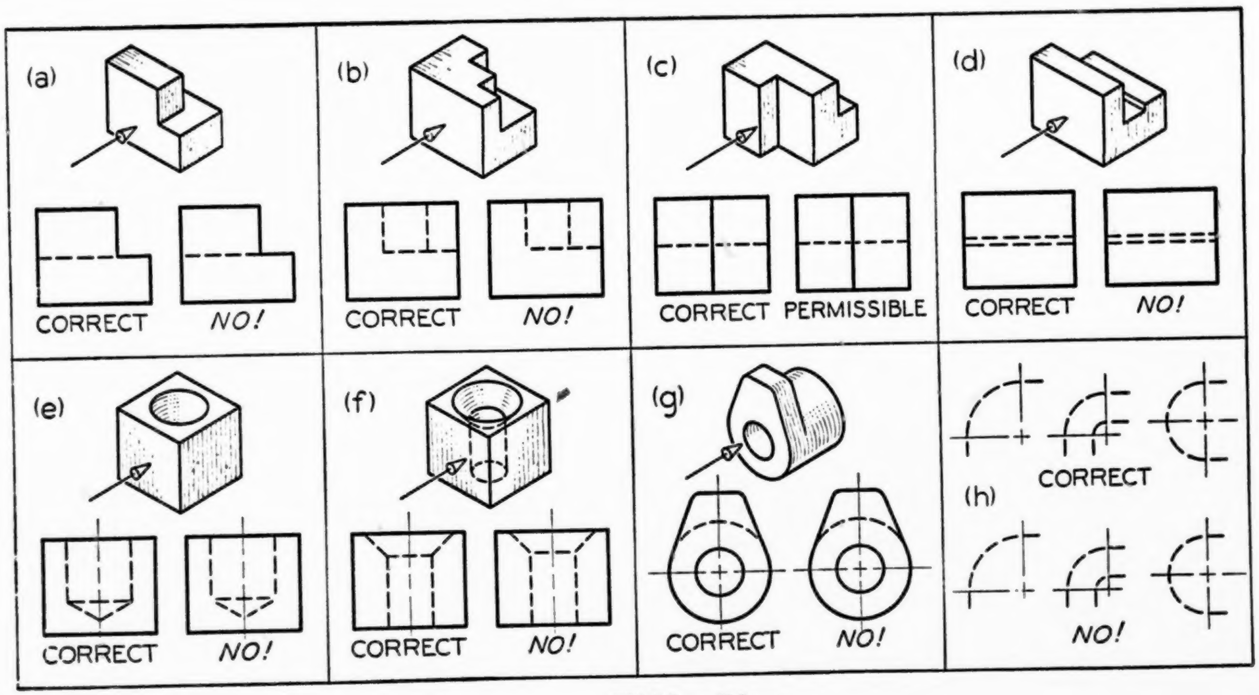

(a)
CORRECT
NO!
(b)
CORRECT
NO!
(c)
CORRECT
PERMISSIBLE
(d)
CORRECT
NO!
(e)
CORRECT
NO!
(f)
CORRECT
NO!
(g)
CORRECT
NO!
(h)
CORRECT
NO!

Figure 11. **Hidden Lines.**

Figure 11 outlines examples of the correct usage of hidden lines, especially where intersections with object lines occur. Study the figures carefully and seek additional information from text references or from the instructor when necessary. Bear in mind that primary consideration should be given to views which have the least number of hidden lines. The elimination of excess hidden lines is important to good drawing techniques.

Partial Views

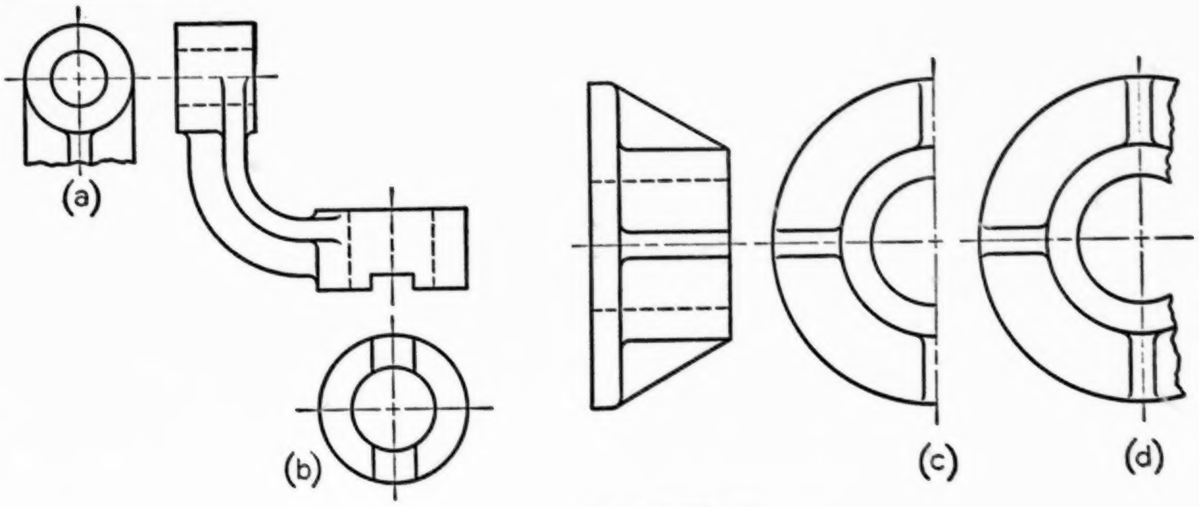


Figure 12. **Partial Views.**

A view of an object need not always be complete to provide adequate description of an object. Such a view is called a PARTIAL VIEW. Examples of partial views are shown in figure 12. A break line (a) may be used to limit the partial view; the contour of the part shown may limit the view (b); or, if symmetrical, a half-view may be drawn on one side of the center line (c); or a partial view "broken out" may be drawn as at (d). The half shown at (c) and (d) should be the "near" side, as shown.

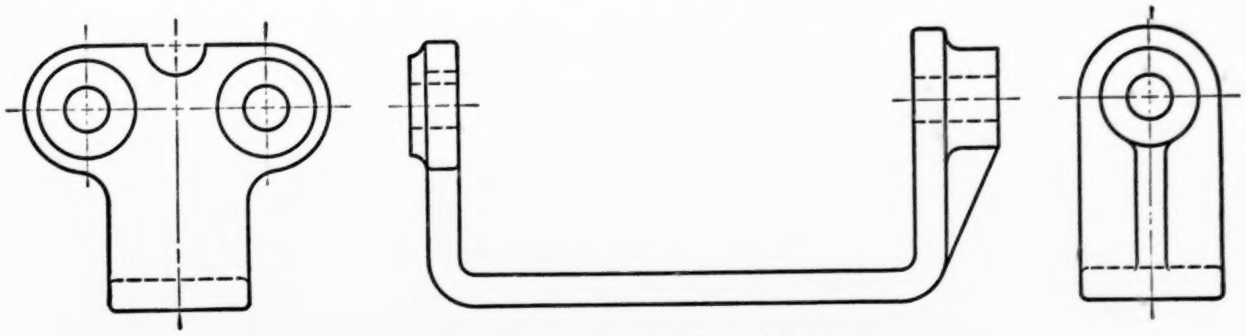
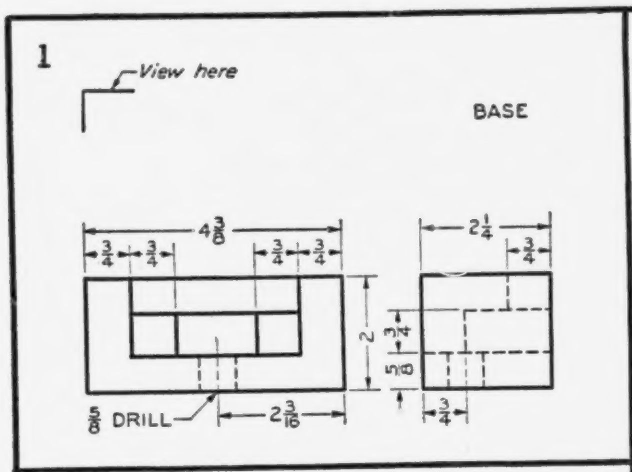


Figure 13. **Incomplete Side Views.**

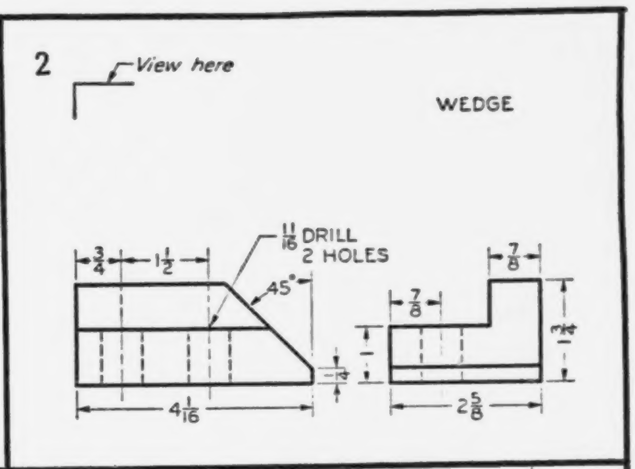
Occasionally, the distinctive features of an object are on opposite sides so that in either complete side view there would be a considerable overlapping of shapes, resulting in an unintelligible view. In such cases, two side views are often the best solution. Observe that the views are partial views in which certain visible and invisible lines have been omitted for clearness.

ASSIGNMENT:

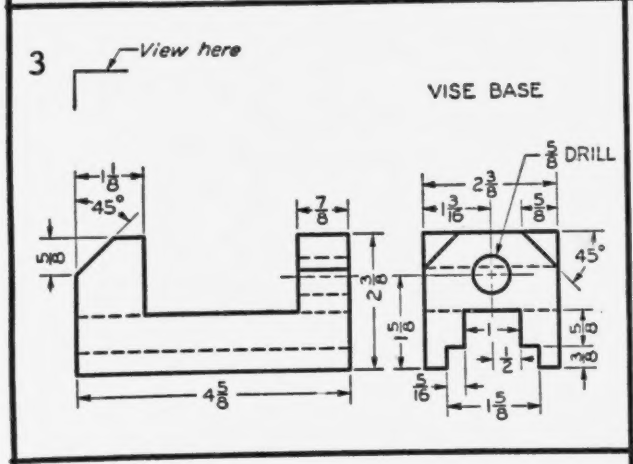
Make a three-view drawing for each of the following problems, 1 - 8, using drawing instruments. Properly arrange the views on size A drawing paper using the simplified title block. Do not attempt to include dimensions or drawing notes. Titles for each problem are given with the sketches.


1

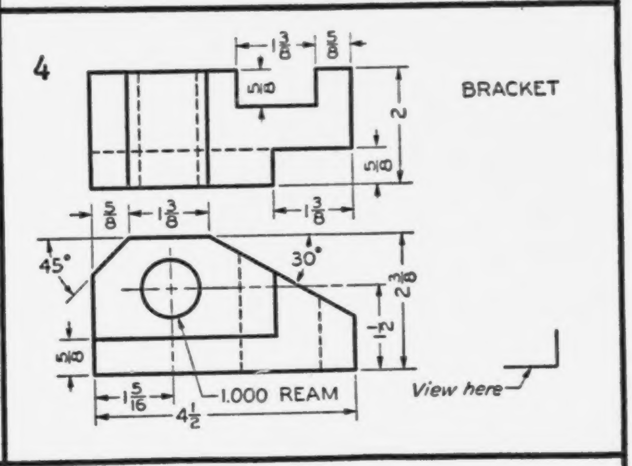
BASE
View here
4 3/8
3/4
3/4
3/4
3/4
2 1/4
3/4
2
3/4
5/8
5/8 DRILL
2 3/16
3/4


2

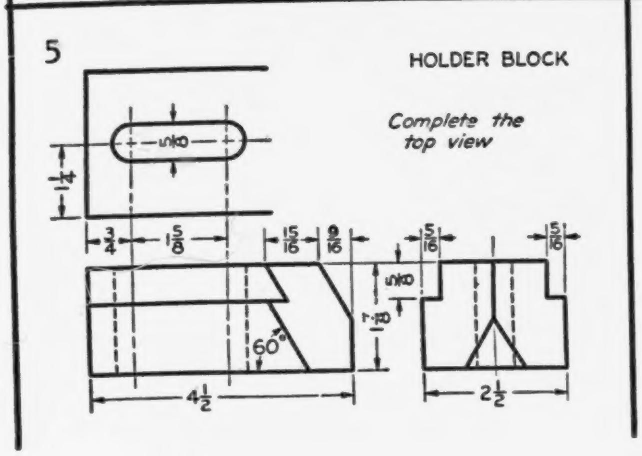
WEDGE
View here
11/16 DRILL
2 HOLES
3/4
1 1/2
45°
7/8
7/8
1 3/4
1
1/4
4 1/16
2 5/8


3

VISE BASE
View here
1 1/8
45°
5/8
7/8
4 5/8
5/8 DRILL
2 3/8
1 3/16
5/8
45°
2 3/8
1 5/8
1
1/2
5/8
3/8
5/16
1 5/8

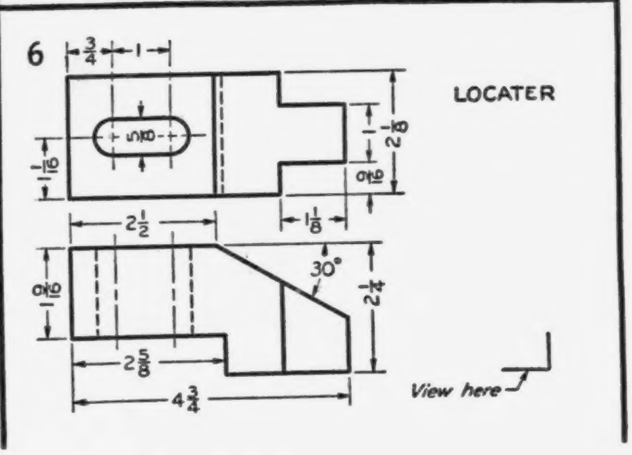

4

BRACKET
1 3/8
5/8
5/8
2
5/8
5/8
1 3/8
1 3/8
45°
30°
2 3/8
1 1/2
5/8
1 5/16
1.000 REAM
4 1/2
View here


5

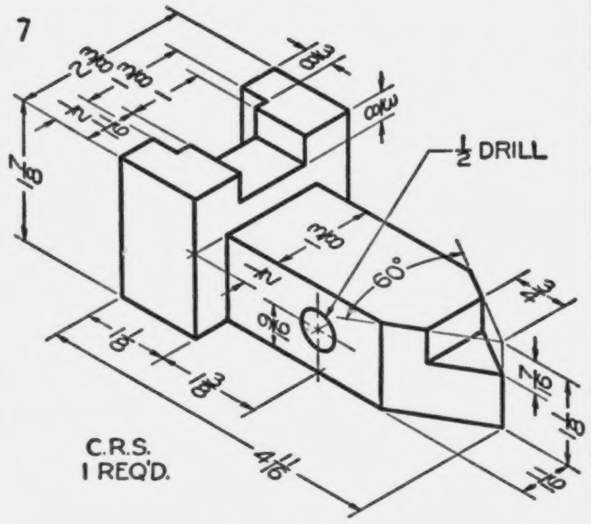
HOLDER BLOCK

Complete the top view
5/8
1 1/4
3/4
1 5/8
15/16
9/16
5/16
5/16
5/8
1 1/8
60°
4 1/2
2 1/2


6

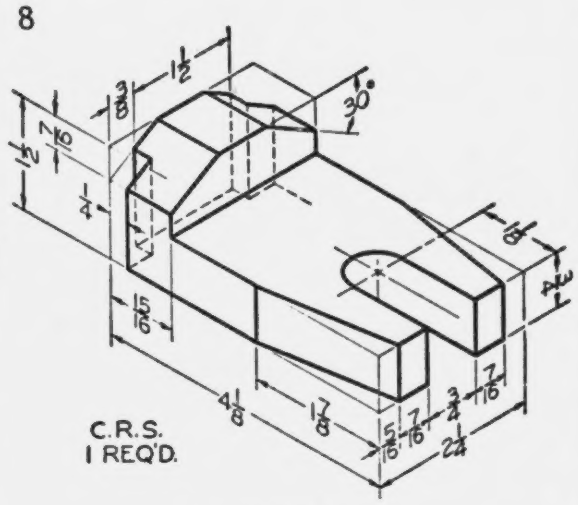
LOCATER
3/4
1
5/8
1 1/16
1
2 1/8
9/16
2 1/2
1 1/8
9/16
1 1/16
30°
2 1/4
2 5/8
4 3/4
View here

7


1/2 DRILL
60°
C.R.S.
1 REQ'D.

Safety Key

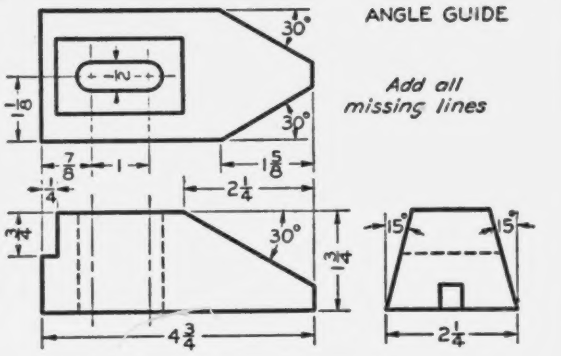
8


1 1/2
30°
4 1/8
1 7/8
2 1/4
C.R.S.
1 REQ'D.

Finger Guide

The following are optional assignments. Do these problems only if you have completed the above assignments. You may do any or all as time permits previous to the introduction of the next unit. Make good use of your time to gain valuable experience.

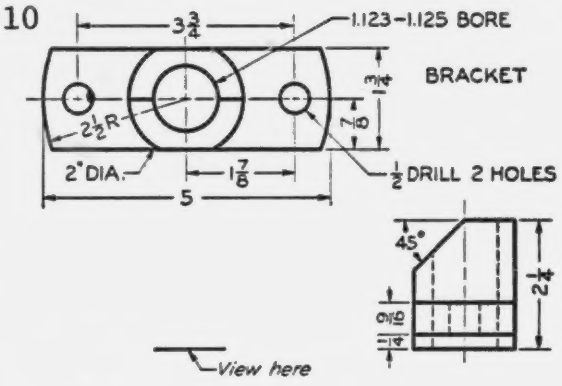
9


30°
30°
1 5/8
2 1/4
30°
4 3/4
15°
15°
2 1/4

ANGLE GUIDE

Add all missing lines

10

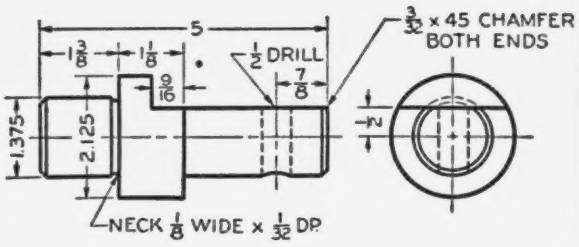

3 3/4
1.123-1.125 BORE
2 1/2 R
2" DIA.
1 7/8
5
1/2 DRILL 2 HOLES
45°
2 1/4
View here

BRACKET

11

ROD HEAD

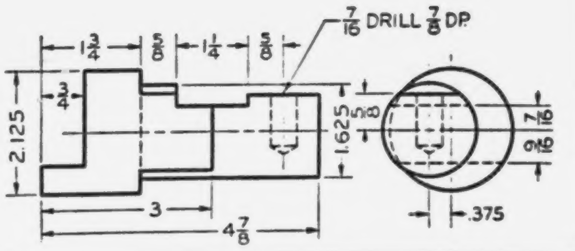
Add top view


5
1 3/8
1 1/8
1/2 DRILL
7/8
3/32 x 45 CHAMFER BOTH ENDS
1.375
2.125
NECK 1/8 WIDE x 1/32 DP.

12

ECCENTRIC

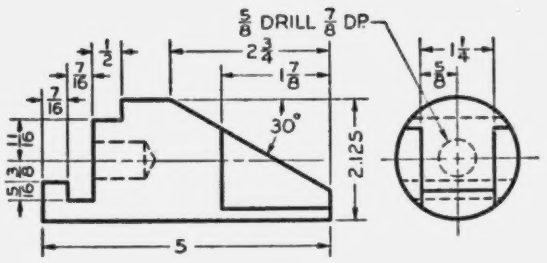
Add top view


1 3/4
5/8
1 1/4
5/8
7/16 DRILL 7/8 DP.
2.125
1.625
3
4 7/8
.375

13

Add top view

WEDGE

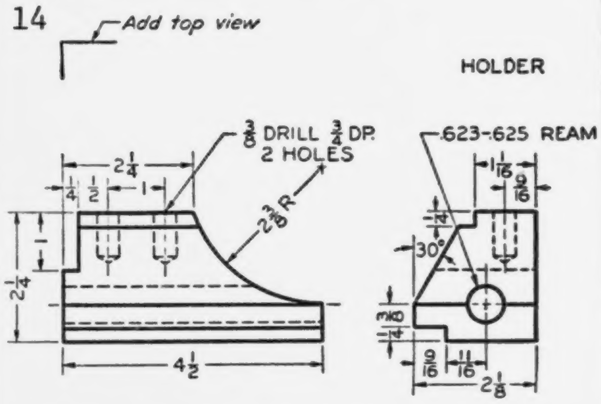


5/8 DRILL 7/8 DP.
1/2
7/16
7/16
2 3/4
1 7/8
1 1/4
5/8
11/16
3/8
5/16
30°
2.125
5

14

Add top view

HOLDER



3/8 DRILL 3/4 DP.
2 HOLES
.623-.625 REAM
2 1/4
1/4
1/2
1
1
2 1/4
2 3/8 R
4 1/2
1 1/16
9/16
1/4
30°
3/8
1/4
9/16
11/16
2 1/8

UNIT III - INTRODUCTION TO DRAWING

Auxiliary Views

Lesson 3

OBJECTIVES:

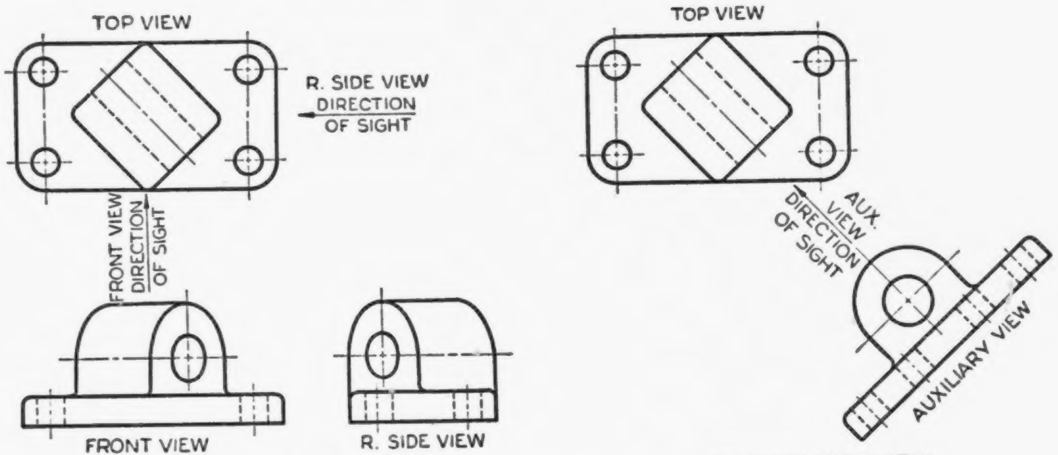
1. To show how auxiliary views are sometimes necessary to supplement the "regular views."
2. To explain "projections" for primary auxiliary views.
3. To show how secondary auxiliary views are derived from primary auxiliaries.

REFERENCES:

1. Chapter 8, TECHNICAL DRAWING, Giesecke, Mitchell, and Spencer.
2. Chapter 9, MECHANICAL DRAWING, French and Svensen.

INFORMATION:

Many objects are of such a form that their principal faces are not always parallel to one of the regular "planes of projection." Figure 1 shows one example where a portion of the object does not appear in its true size and shape in any of the three regular views.


TOP VIEW
R. SIDE VIEW DIRECTION OF SIGHT
FRONT VIEW DIRECTION OF SIGHT
FRONT VIEW
R. SIDE VIEW
TOP VIEW
AUX. VIEW DIRECTION OF SIGHT
AUXILIARY VIEW

(a) REGULAR VIEWS

(b) AUXILIARY VIEW

Figure 1. **Regular Views and Auxiliary Views.**

In order to show the true circular shapes, it is necessary to assume a direction of sight that is perpendicular to the planes of those curves. The resulting view is called an AUXILIARY VIEW. This view, together with the top view, adequately describes the object. Those regular views, which are not necessary, are eliminated; in this case, the front and right side views.

Classification of Auxiliary Views

An auxiliary view may be projected from a position perpendicular to any one of the three existing planes. Auxiliary views are named according to the principal dimension of the object shown in that auxiliary view.

For example, any auxiliary view projected from the front view will show the depth of the object and is called a DEPTH AUXILIARY. Similarly, any auxiliary view projected from the top view is a HEIGHT or ELEVATION AUXILIARY, and any auxiliary view projected from either side view is a WIDTH AUXILIARY.

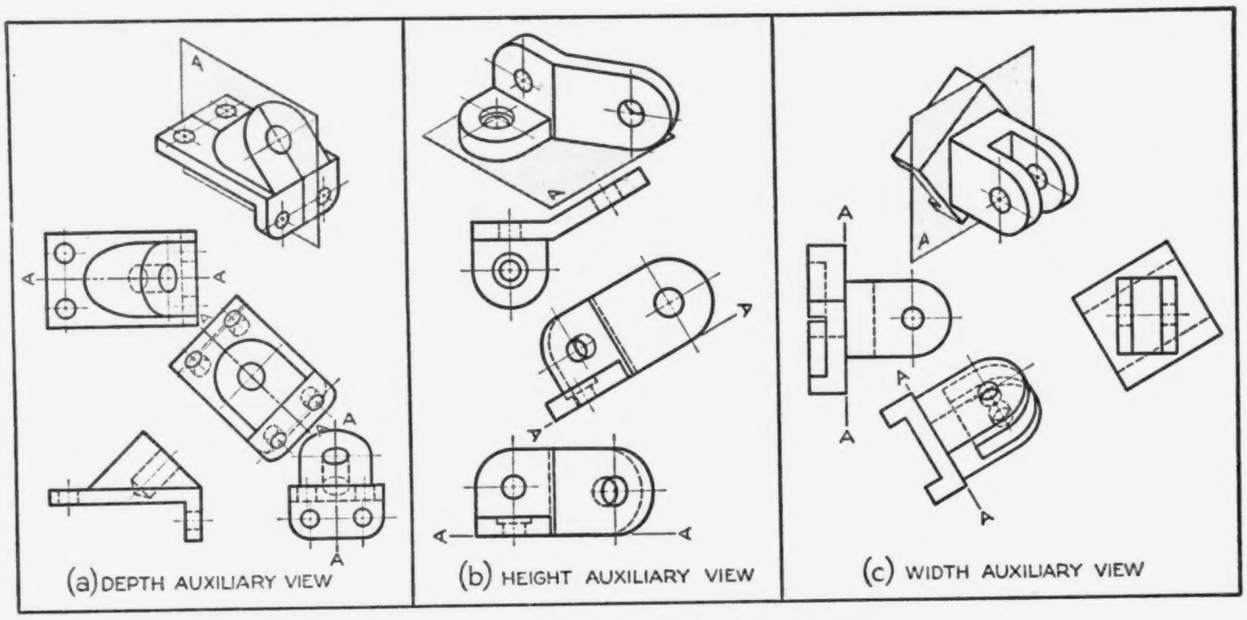

A
A
A
(a) DEPTH AUXILIARY VIEW
(b) HEIGHT AUXILIARY VIEW
(c) WIDTH AUXILIARY VIEW

Figure 2. **Primary Auxiliary Views.**

Partial Auxiliaries

As we have already seen, there are cases when not all of the "regular views" of an object are necessary in the presence of an auxiliary view. However, in the case of figure 2, you will notice that at least a portion of each of the views is necessary to describe the object adequately. The work represented is quite confusing and could not be well used as a working drawing due to the "clutter of lines" and ellipses involved.

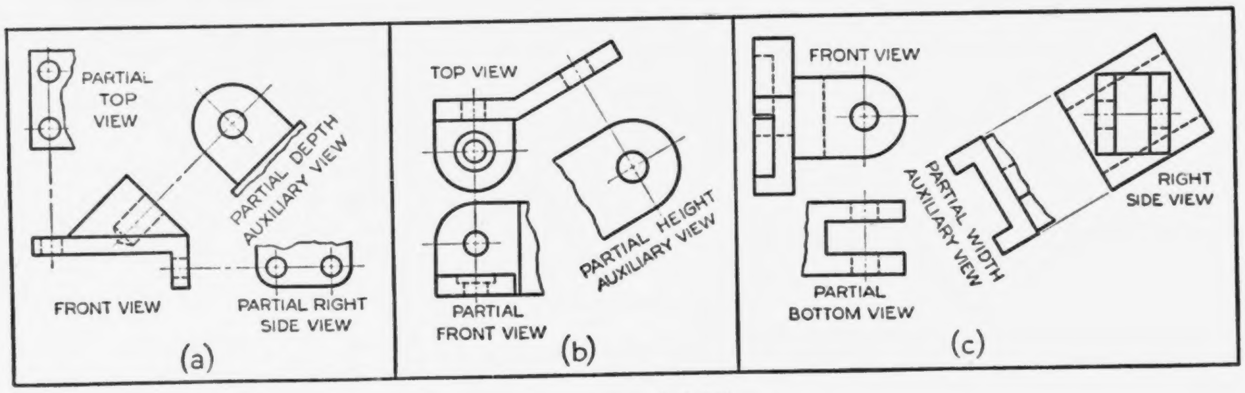

PARTIAL TOP VIEW
PARTIAL DEPTH AUXILIARY VIEW
FRONT VIEW
PARTIAL RIGHT SIDE VIEW
(a)
TOP VIEW
PARTIAL HEIGHT AUXILIARY VIEW
PARTIAL FRONT VIEW
(b)
FRONT VIEW
PARTIAL WIDTH AUXILIARY VIEW
RIGHT SIDE VIEW
PARTIAL BOTTOM VIEW
(c)

Figure 3. **Partial Views.**

Figure 3 demonstrates how the amount of work necessary to describe the same problems used in figure 2 can be greatly reduced by the use of partial auxiliary views. You will notice that the use of partial regular views also is applied here. In deciding when to use partial auxiliary views, the following conditions should be considered:

1. When the auxiliary view is symmetrical.
2. If the desired description applies to only a portion of the object.
3. If it is necessary to save space in the drawing or to save drafting time.

Notice that in each case in figure 3, as is true of partial regular views, that portion of the object nearest the plane of reference is shown.

Use of Hidden Lines in Auxiliary Views

An effort should be made to eliminate hidden lines from auxiliary views unless they are needed for clarity. As a beginning draftsman, the student should include all necessary hidden lines, especially if the entire view is drawn. In later, more advanced work it will become apparent as to when and where hidden lines can be omitted.

Drawing Primary Auxiliary Views

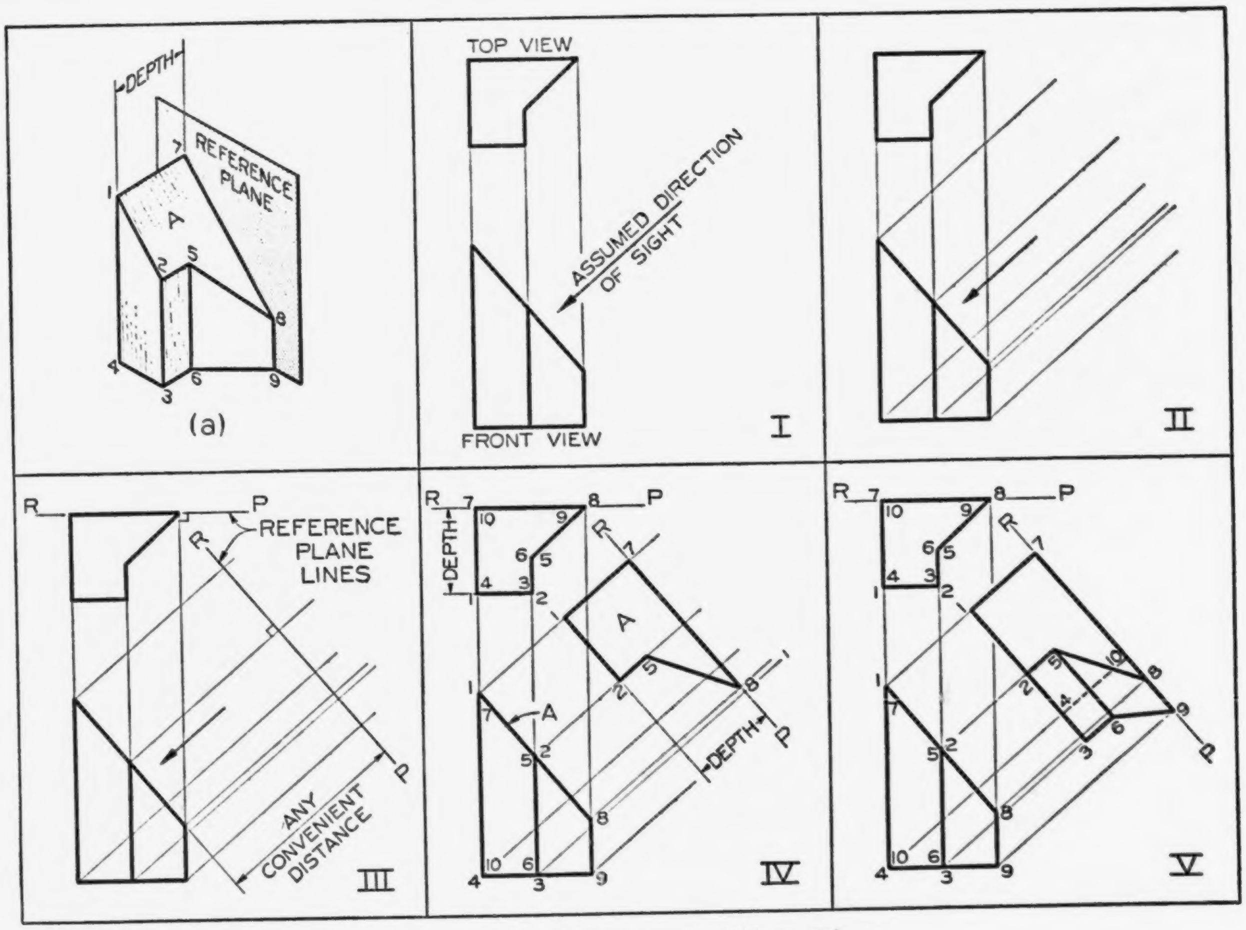

DEPTH
REFERENCE PLANE
A
1
2
3
4
5
6
7
8
9
(a)
TOP VIEW
ASSUMED DIRECTION OF SIGHT
FRONT VIEW
I
II
R
P
REFERENCE PLANE LINES
ANY CONVENIENT DISTANCE
III
DEPTH
10
IV
V

Figure 4. To Draw an Auxiliary View.

Figure 4 demonstrates the step-by-step construction of a primary auxiliary view. A primary auxiliary view is one which is projected perpendicular to the surface being viewed. In this case, a right side or DEPTH auxiliary is illustrated.

Establish a plane of reference against which one side of the auxiliary view will be located (a). From this angle (usually a straight side), the remainder of the view is drawn.

I. Draw two views of the object omitting the regular view to be replaced by the auxiliary. Establish the assumed direction of sight (indicate by the arrow).

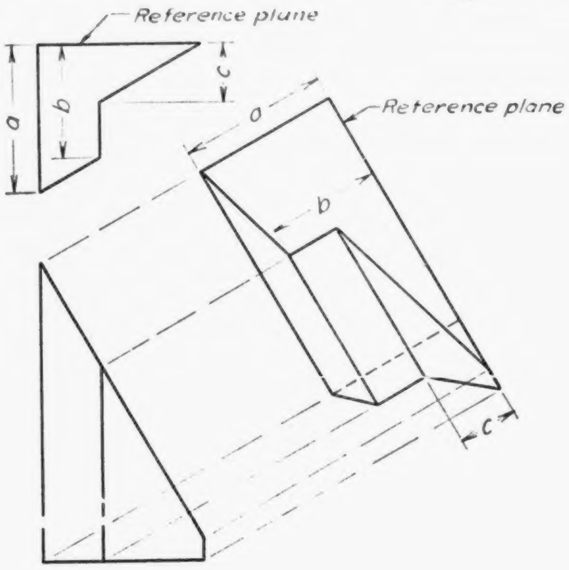
II. Draw projectors parallel to the direction of sight.

III. Draw reference lines in the top and auxiliary views at right angles to the projectors. THESE ARE THE EDGE VIEWS OF THE REFERENCE PLANE.

IV. Draw the auxiliary view of the surface A. It will be shown in its true size and shape because the direction of sight was taken perpendicular to that surface. Transfer depth measurements (see figure 8, lesson 2) from the top view to the auxiliary view with dividers or scale. Each point in the auxiliary view will be located on its projection line from the front view and the same distance from the reference line as it is in the top view to the corresponding reference line.

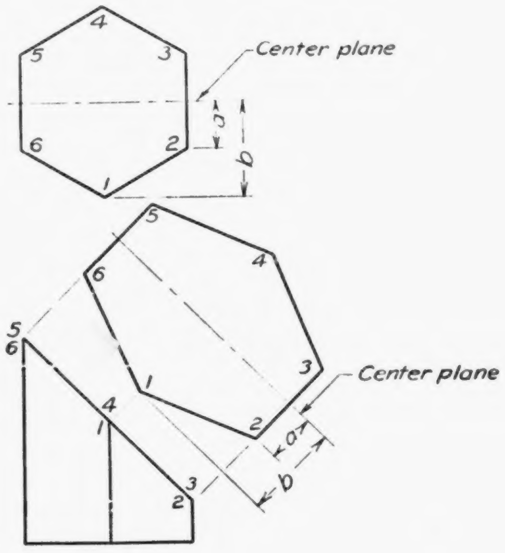
V. Complete the auxiliary view by adding other visible edges and surfaces of the object. Each numbered point in the auxiliary view lies on its projector from the front view, and is the same distance from the reference plane as it is in the top view.

Figure 5.



Auxiliary view from reference plane.

Figure 6.



Auxiliary view from center plane.

Auxiliary views may be drawn by establishing a reference plane with the object (figure 5) or by using a center reference (figure 6) which is especially applicable to symmetrical objects. Remember that the entire auxiliary need not always be drawn. Use partial views to describe objects when possible to do so without forsaking clarity.

Figure 7 illustrates a practical application of the method of drawing parallel lines discussed earlier in Geometric Constructions (page 47).

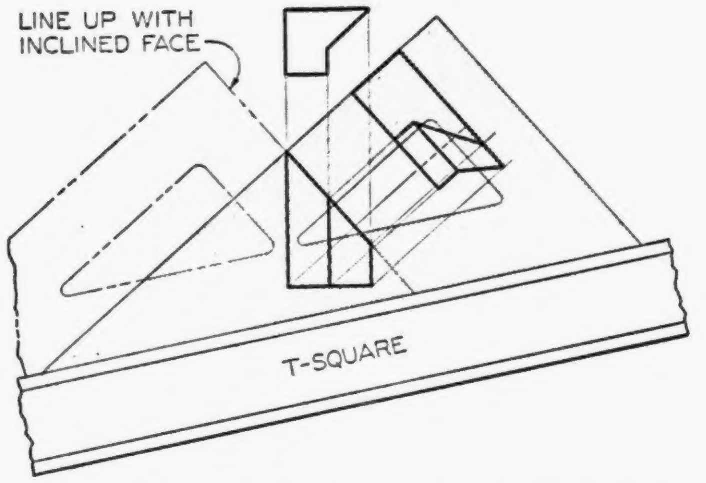


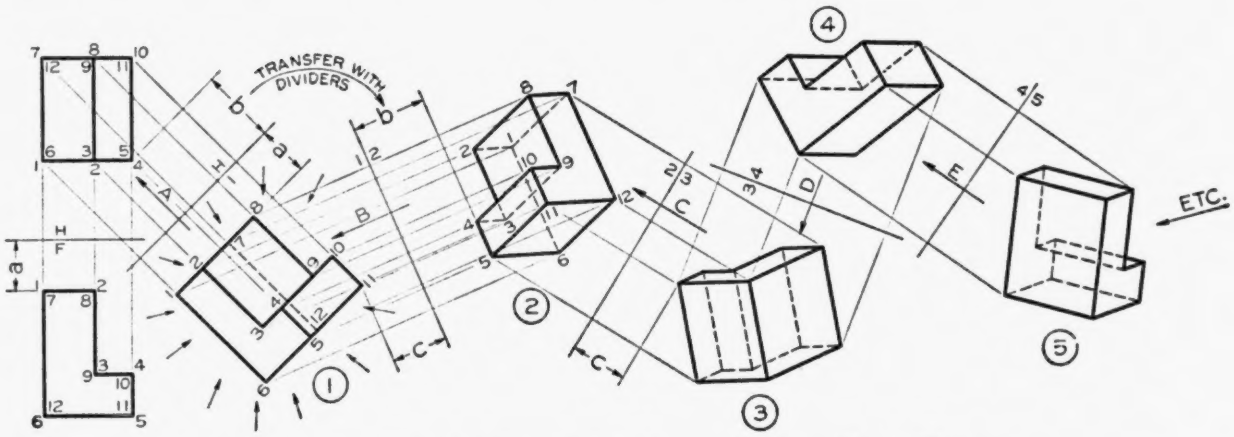
Figure 7.

Drawing Parallel or Perpendicular Lines.

Secondary Auxiliary Views

Thus far only primary auxiliary views have been discussed (single views projected from one of the regular views of the object).

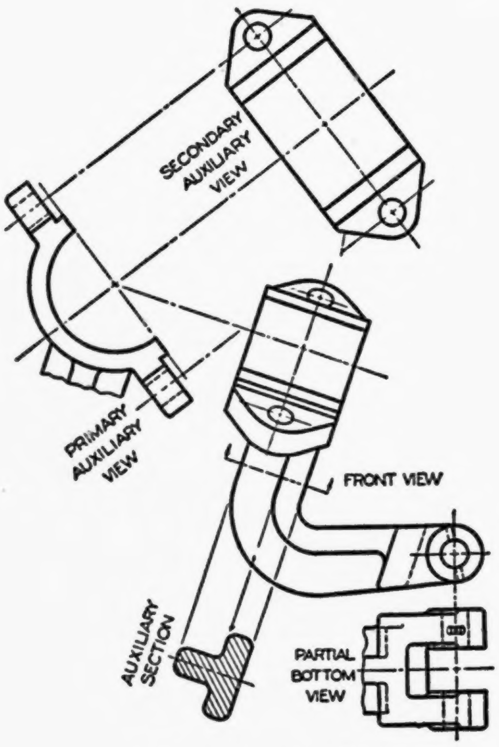
SECONDARY AUXILIARY VIEWS are those which can be projected from primary auxiliaries. Figure 8 shows a primary auxiliary view projected from the top view of an object. From primary auxiliary view (1) a secondary auxiliary (2) can be drawn, from it a third (3), and so on. An infinite number of secondary auxiliaries can be drawn, a process which may be likened to a "chain reaction" in nuclear fission.



"Chain Reaction"—Successive Auxiliary Views.

Figure 8.

The secondary auxiliary (2) is not the only one that can be projected from the primary views, however, as shown by the arrows around view (1).



Secondary Auxiliary View.

The purpose behind secondary auxiliary views is to provide a means of further describing the object beyond what can be attained in the primary auxiliary. One example of this can be seen in figure 9, where the primary auxiliary provides a left side description of the bearing ring. The secondary auxiliary shows the top surface of the bearing providing a clear view of drilled hole locations on the lugs.

Remember, all drawing work should attain the desired description of the object with a minimum of effort. TIME IS MONEY in the drafting room.

Figure 9.

QUESTIONS:

1. What is the function of an auxiliary view?
2. What is a primary auxiliary view?
3. What is a secondary auxiliary view?
4. Why is the reference plane important?
5. What is an elevation auxiliary, and how is it projected?
6. What is a partial auxiliary? What is its purpose?
7. Where does the center reference method of drawing auxiliaries apply?
8. How do we name auxiliary views?

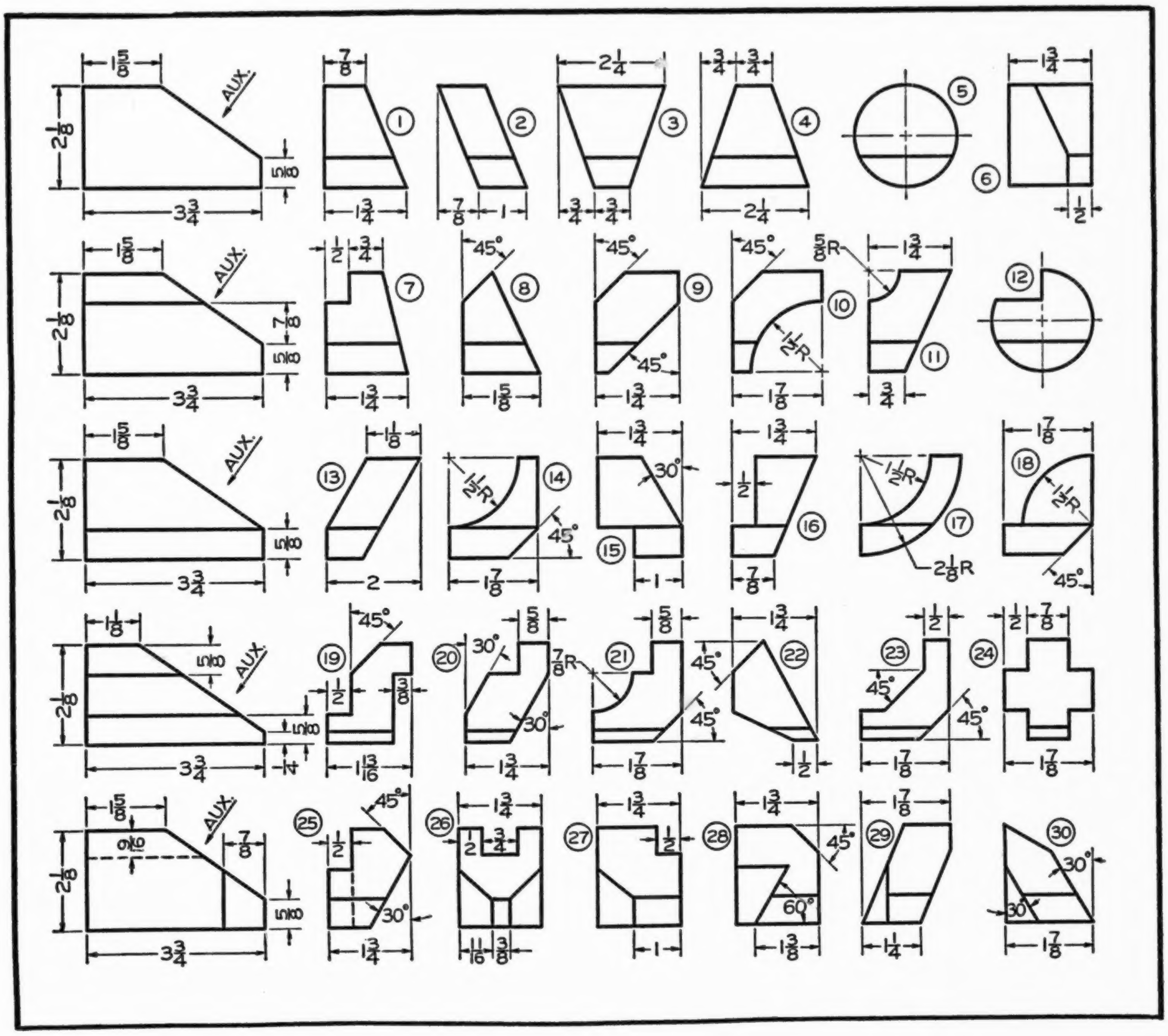
9. What regular view is replaced when auxiliaries are drawn?

10. What is meant by "direction of sight"?

ASSIGNMENT:

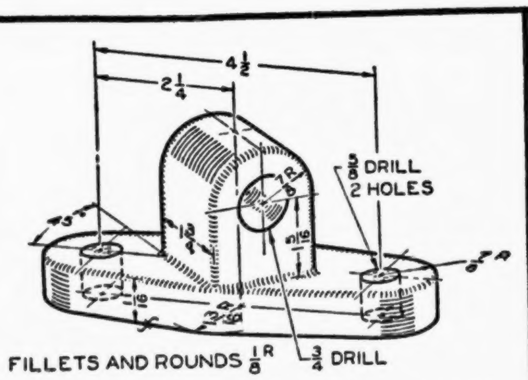
The following series of problems include a given front view and several possible right side views. Do one problem from each of the five columns, following the instructor's assignments.

Draw the entire auxiliary view including all surfaces of the objects in Problem 1. Work is to be done on size A paper with a simplified title block. Omit dimensions. Title: PRIMARY AUXILIARY.


AUX.
AUX.
AUX.
AUX.
AUX.
①
②
③
④
⑤
⑥
⑦
⑧
⑨
⑩
⑪
⑫
⑬
⑭
⑮
⑯
⑰
⑱
⑲
⑳
㉑
㉒
㉓
㉔
㉕
㉖
㉗
㉘
㉙
㉚
45°
30°
60°

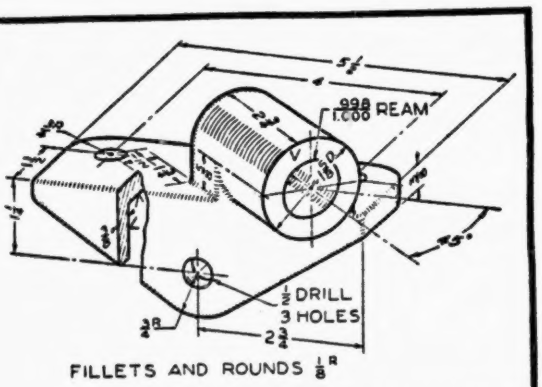
Problem 1.

Problems 2 through 8 are to be drawn on size B paper using the simplified title block. Draw only partial views where required. Use the space on your paper effectively.


4 1/2
2 1/4
7/8 R
5/8 DRILL
2 HOLES
45°
1 3/4
5/16
7/8 R
3/4 DRILL
FILLETS AND ROUNDS 1/8 R

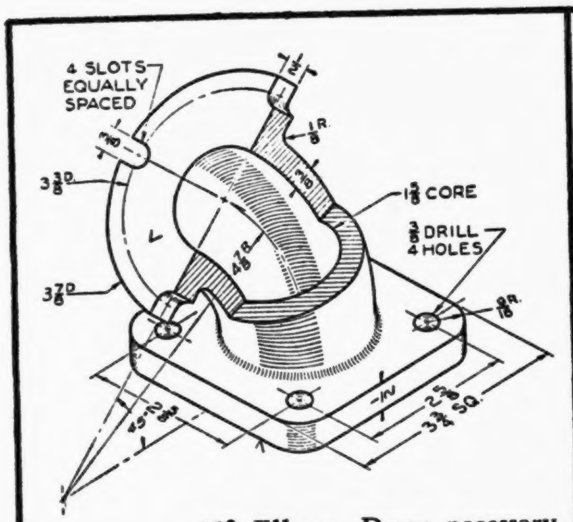
Rod Guide. Draw necessary views, including complete Auxiliary view showing true shape of upper rounded portion

Problem 2.


5 1/2
4
2 3/4
.998/1.000 REAM
1 5/8 D
1 1/2
45°
1/2 DRILL
3 HOLES
3/4 R
2 3/4
FILLETS AND ROUNDS 1/8 R

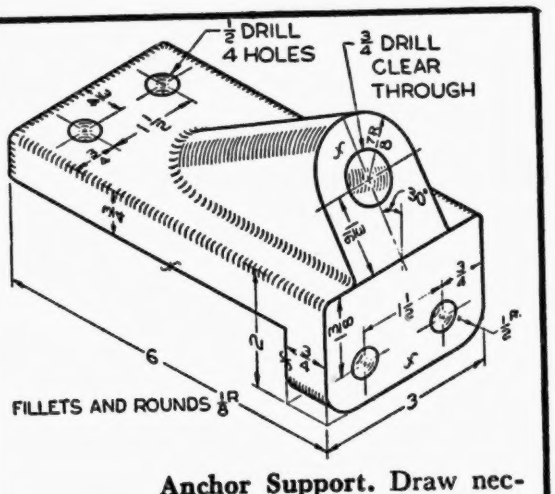
Brace Anchor. Draw necessary views, including partial Auxiliary view showing true shape of cylindrical portion

Problem 3.


4 SLOTS
EQUALLY
SPACED
1/2
1/8 R.
3 3/8 D
1 3/8 CORE
3/8 DRILL
4 HOLES
3 7/8 D
4 7/8 R
9/16 R.
2 5/8
3 3/4 SQ.
45°

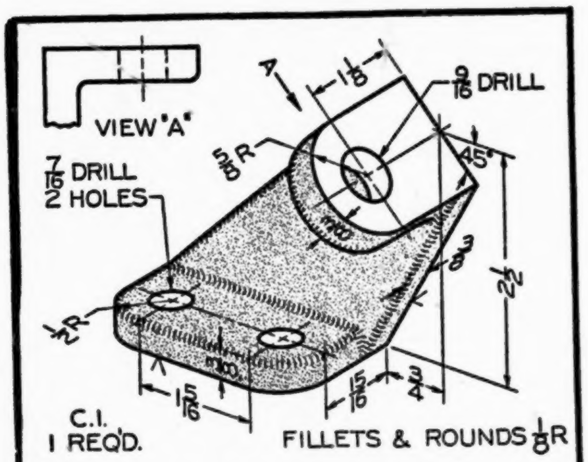
45° Elbow. Draw necessary views, including a broken section and two half views of flanges

Problem 4.


1/2 DRILL
4 HOLES
3/4 DRILL
CLEAR
THROUGH
1 1/2
7/8 R
30°
3/4
1 1/2
1/2 R.
6
2
3
FILLETS AND ROUNDS 1/8 R

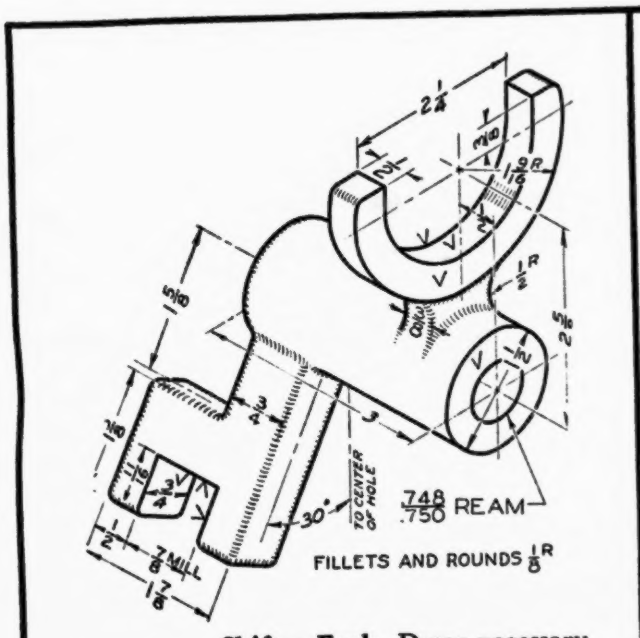
Anchor Support. Draw necessary views, including partial Auxiliary view showing true shape of upper rounded portion, and partial views showing upper left end and lower right end

Problem 5.


VIEW "A"
A
$1\frac{1}{8}$
$\frac{9}{16}$ DRILL
$\frac{5}{8}$R
45°
$\frac{7}{16}$ DRILL
2 HOLES
$\frac{3}{4}$
$2\frac{1}{2}$
$\frac{1}{2}$R
$1\frac{5}{16}$
$\frac{15}{16}$
$\frac{3}{4}$
C.I.
1 REQ'D.
FILLETS & ROUNDS $\frac{1}{8}$R

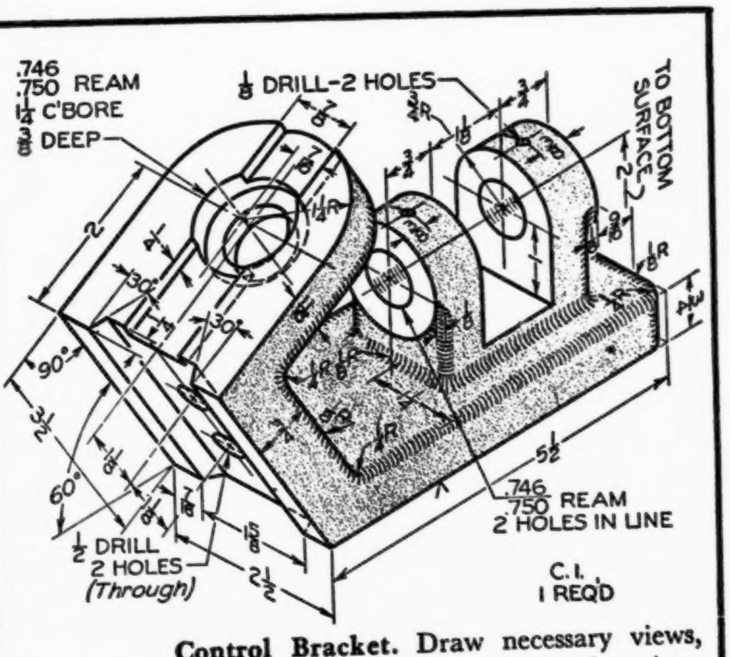
Anchor Bracket. Draw necessary views or partial views

Problem 6.


$2\frac{1}{4}$
$\frac{1}{2}$
$\frac{3}{16}$
$\frac{9}{16}$R
$\frac{1}{2}$R
$1\frac{5}{8}$
$2\frac{5}{8}$
$\frac{1}{2}$
$1\frac{3}{8}$
$\frac{3}{4}$
$\frac{3}{16}$
30°
TO CENTER OF HOLE
$\frac{.748}{.750}$ REAM
$\frac{7}{8}$ MILL
$1\frac{7}{8}$
2
FILLETS AND ROUNDS $\frac{1}{8}$R

Shifter Fork. Draw necessary views, including partial Auxiliary view showing true shape of inclined arm

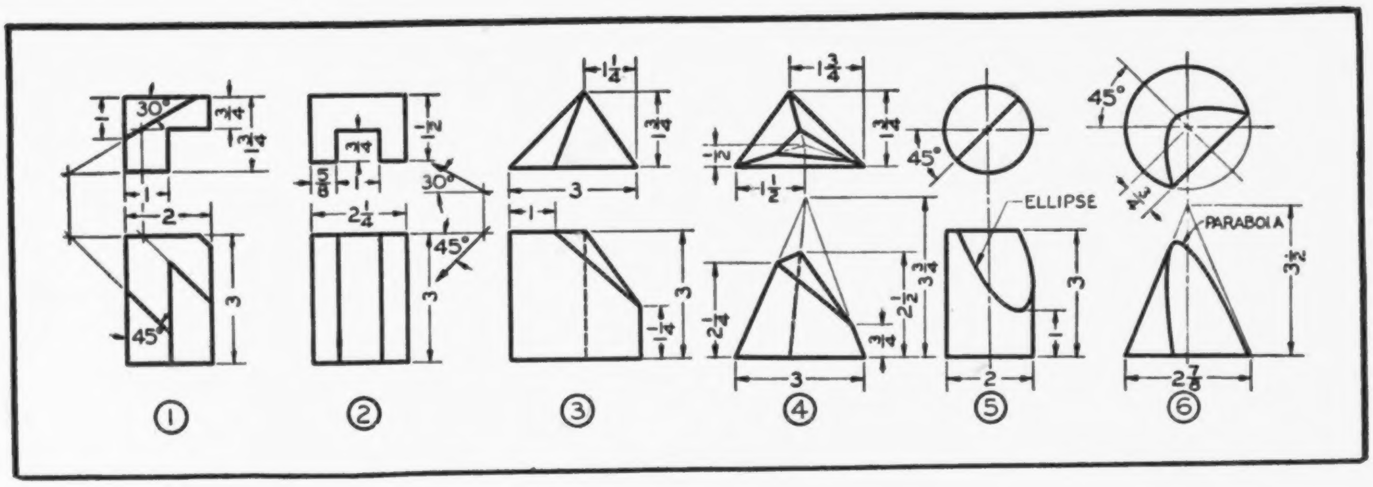
Problem 7.


$\frac{.746}{.750}$ REAM
$1\frac{1}{4}$ C'BORE
$\frac{3}{8}$ DEEP
$\frac{1}{8}$ DRILL-2 HOLES
$\frac{3}{4}$
$\frac{3}{8}$R
TO BOTTOM SURFACE 2
$\frac{1}{8}$R
2
30°
90°
$3\frac{1}{2}$
60°
$\frac{1}{2}$ DRILL
2 HOLES
(Through)
$\frac{7}{8}$
$\frac{15}{8}$
$2\frac{1}{2}$
$5\frac{1}{2}$
$\frac{.746}{.750}$ REAM
2 HOLES IN LINE
C.I.
1 REQ'D

Control Bracket. Draw necessary views, including partial Auxiliary views and regular views

Problem 8.

Problem 9 includes six separate assignments. Do the assigned problems on size B drawing paper. Draw secondary auxiliary views (except #2) which will show the true sizes of the inclined surfaces. In #2, draw secondary auxiliary view as seen in direction of the arrow. Title: SECONDARY AUXILIARY.


30°
1
3/4
3/4
1
2
45°
3
①
3/4
1/2
5/8
1
2 1/4
30°
45°
3
②
1 1/4
3/4
3
1
3
1 1/4
③
1 3/4
3/4
1/2
1 1/2
3 3/4
2 1/2
2 1/4
3/4
3
④
45°
ELLIPSE
3
1
2
⑤
45°
3/4
PARABOLA
3 1/2
2 7/8
⑥

Problem 9.

UNIT IV - WORKING DRAWING INTERPRETATION

Dimensioning Lesson 1

OBJECTIVES:

1. To introduce dimensioning as it applies to orthographic drawing.
2. To introduce the use of the scale in drawing.
3. To introduce dimensioning techniques for holes, angles, and special shapes.
4. To introduce working drawing notation techniques.

REFERENCE:

1. Chapter 11, TECHNICAL DRAWING, Giesecke, Mitchell, and Spencer.

INFORMATION:

In previous lessons as well as in following lessons, methods of providing adequate SHAPE DESCRIPTION of objects are discussed. Working drawings also require complete SIZE DESCRIPTION. This is provided through dimensioning.

Well formed figures and word notations (penmanship) on drawings are very important to the reading and understanding of your drawings. Continually make efforts to improve your drawing skill, especially as it applies to lettering and dimensioning. The following information is provided to introduce techniques for the making of working drawings. You must supply the skill brought about by applied effort.

Purpose of Dimensions

With the ever increasing need for extreme accuracy of machined parts, particularly for the purposes of interchangeability, responsibility for size control has shifted from the machinist to the engineer and the draftsman. The workman is no longer concerned with the design and engineering of the part, but is only interested in the proper execution of drawing instructions. The part will be only as good as the instructions given.

The drawing should contain all information necessary to show the part in its finished state and to bring it to that state. Good dimensioning, then, is extremely important. Not only are sizes important, but also the notes and tolerances which must accompany them. Without complete dimensioning, the relationships of parts and drawings would be impossible.

To Indicate the Scale on a Drawing

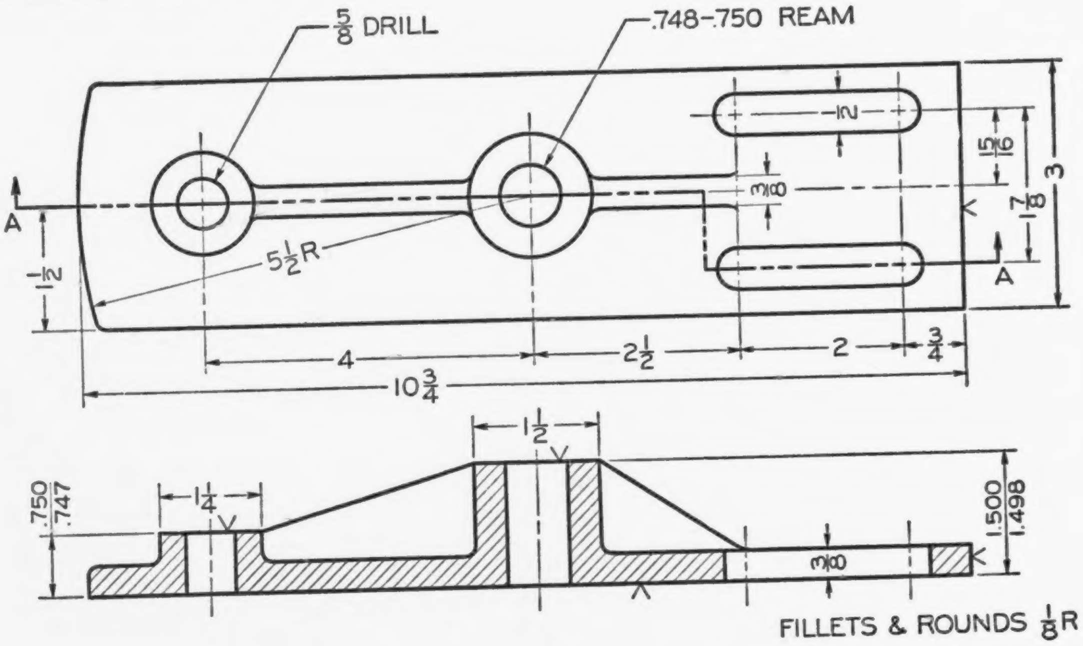
Space has been provided in the working drawing title block format for the indication of scale on your drawings.

For machine drawings, the most common practice is to letter FULL SIZE, $\frac{1}{2}$ SIZE, $\frac{1}{4}$ SIZE, or $\frac{1}{8}$ SIZE; or to abbreviate with the words FULL, HALF, QUARTER, or EIGHTH; or to equate inches to inches, as 1" = 1", $\frac{1}{2}$" = 1", $\frac{1}{4}$" = 1", $\frac{1}{8}$" = 1", or 2" = 1" (double size). For examples of how scales are shown on machine drawings, see Unit II, Lesson 2, figure 1 (page 27).

For classwork purposes, write the word FULL for all full scale drawings and equate in inches all other scales as outlined above.

BASIC DIMENSIONING TECHNIQUES

Character of Lines



$\frac{5}{8}$ DRILL
.748-.750 REAM
A
$1\frac{1}{2}$
$5\frac{1}{2}$R
$\frac{1}{2}$
$\frac{3}{8}$
$\frac{15}{16}$
$1\frac{7}{8}$
3
A
4
$2\frac{1}{2}$
2
$\frac{3}{4}$
$10\frac{3}{4}$
$1\frac{1}{2}$
$1\frac{1}{4}$
.750
.747
$\frac{3}{8}$
1.500
1.498
FILLETS & ROUNDS $\frac{1}{8}$R

Technique of Dimensioning.

Figure 1.

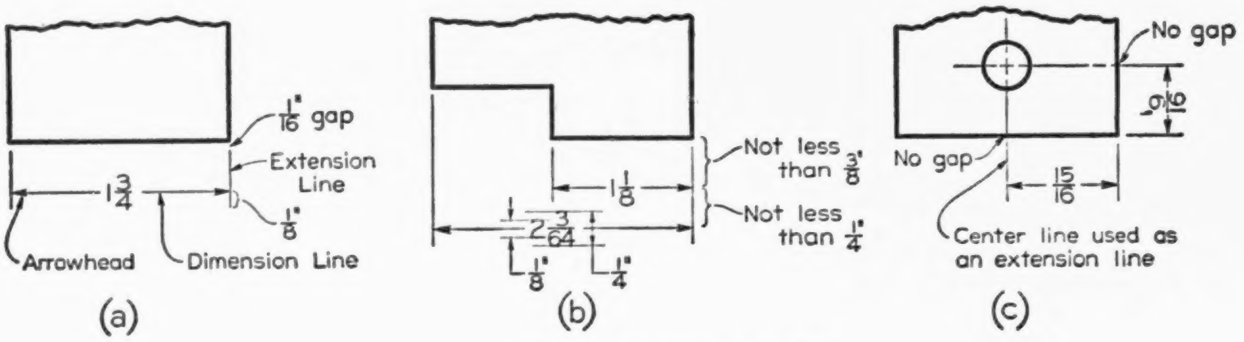
If lines are made correctly on drawings, strong contrasts will be noticed between visible lines and dimension lines.

Also important to the character of dimensioning is the proper spacing of dimensions, formation of arrowheads, placements of dimensions, and the proper choice of dimensions. Choice of dimensions should be made based on the function of the part, describing the size of all details, and then adding notes to provide additional information from the standpoint of the shop without affecting the functional dimensioning.

Lines Used in Dimensions

A DIMENSION LINE, figure 2(a), is a fine, dark, solid line terminated by arrowheads, which indicates the direction and extent of a dimension.

In machine drawings in which common fractions are used, the line is broken usually near the middle to provide an open space for the dimension figure.


$\frac{1}{16}$" gap
Extension Line
$1\frac{3}{4}$
$\frac{1}{8}$"
Arrowhead
Dimension Line
(a)
$1\frac{1}{8}$
$2\frac{3}{64}$
$\frac{1}{8}$"
$\frac{1}{4}$"
Not less than $\frac{3}{8}$"
Not less than $\frac{1}{4}$"
(b)
No gap
$\frac{9}{16}$
No gap
$\frac{15}{16}$
Center line used as an extension line
(c)

Dimensioning Technique.

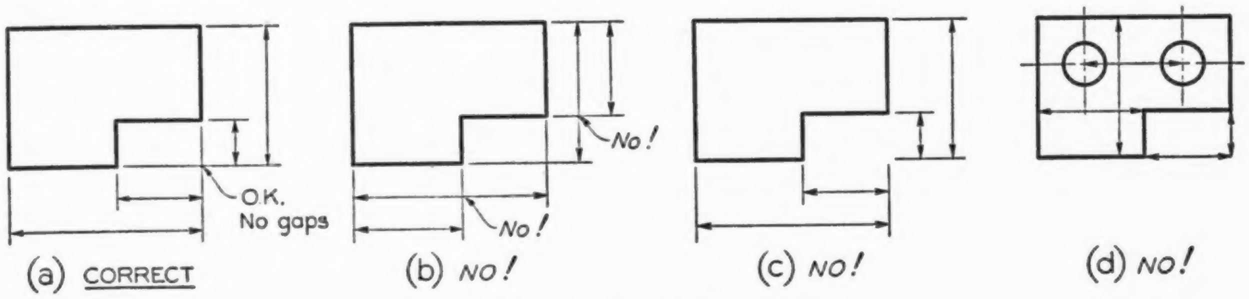
Figure 2.

As shown at (b), the dimension line nearest the object outline should be spaced at least $\frac{3}{8}$" away. All other parallel dimension lines should be at least $\frac{1}{4}$" apart, and more if space is available. THE SPACING OF DIMENSION LINES SHOULD BE UNIFORM THROUGHOUT THE DRAWING.

An EXTENSION LINE, (a), is a fine, dark, solid line that "extends" from a point on the drawing to which a dimension refers. The dimension line meets the extension lines at right angles except in special cases (a). A gap of about $\frac{1}{16}$" should be left where the extension line would join the object outline. The extension line should extend about $\frac{1}{8}$" beyond the outermost arrowhead (a) and (b).

A CENTER LINE is a fine, dark line composed of alternate long and short dashes, and is used to represent axes of symmetrical parts and to denote centers. As shown in figure 2(c), center lines are commonly used as extension lines in locating holes and other features. When so used, the center line crosses over other lines of the drawing without gaps. A center line should always end in a long dash.

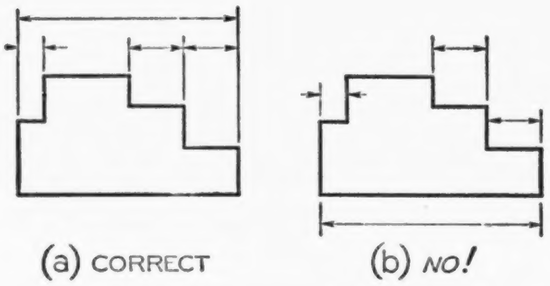
Placement of Dimension and Extension Lines


O.K. No gaps
(a) CORRECT
No!
No!
(b) NO!
(c) NO!
(d) NO!

Dimension and Extension Lines.

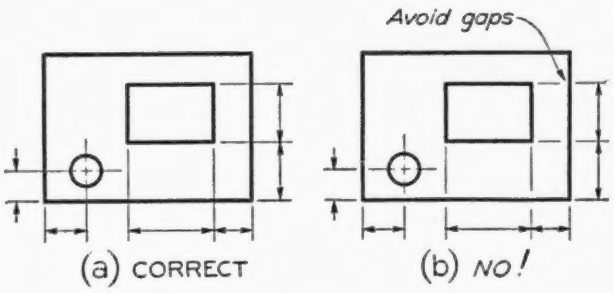
Figure 3.

A correct example of the placement of dimension lines and extension lines is shown in figure 3(a). The shorter dimensions are nearest to the object outline. Dimension lines should not cross extension lines as at (b), which results from placing the shorter dimensions outside. Note that it is perfectly satisfactory to cross extension lines as shown at (a). They should never be shortened as at (c). A dimension line should never coincide with or form a continuation of any line of the drawing as shown at (d). Avoid crossing dimension lines wherever possible.


(a) CORRECT (b) *NO!*

Grouped Dimensions.

Figure 4.



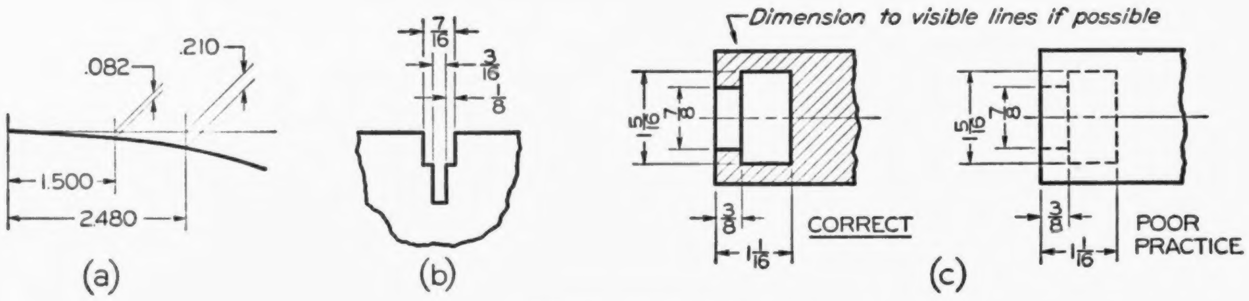
(a) CORRECT (b) *NO!*

Crossing Lines.

Figure 5.

Dimensions should be lined up and grouped together as much as possible as shown in figure 4(a), and not as at (b).

In many cases, extension lines and center lines must cross visible lines of the object, figure 5(a). When this occurs, gaps should not be left in the lines as at (b).



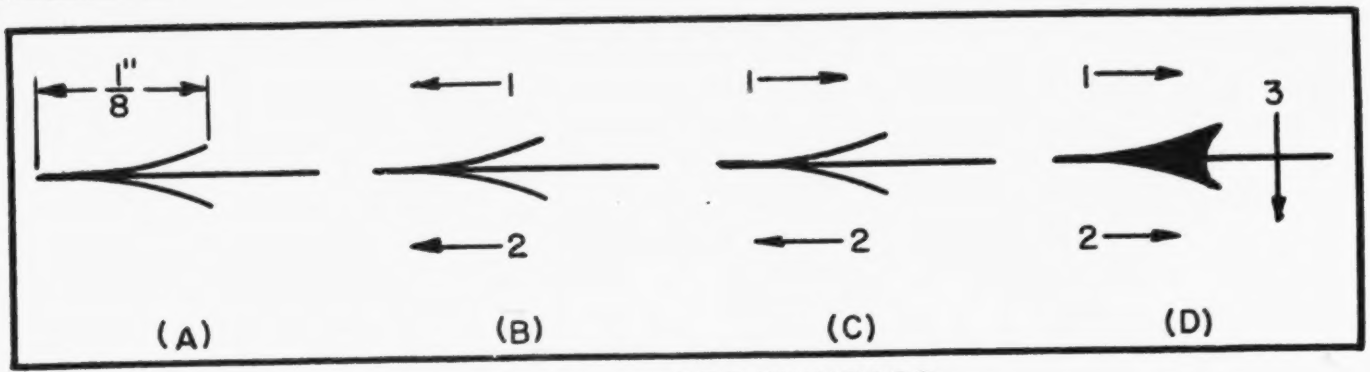
(a) (b) (c)

Placement of Dimensions.

Figure 6.

Dimension lines are normally drawn at right angles to extension lines, but an exception may be made in the interest of clearness as shown in figure 6(a). In crowded conditions, gaps in extension lines near arrowheads may be left in order to clarify the dimensions as shown at (b). In general, avoid dimensioning to hidden lines as shown at (c).

Arrowheads



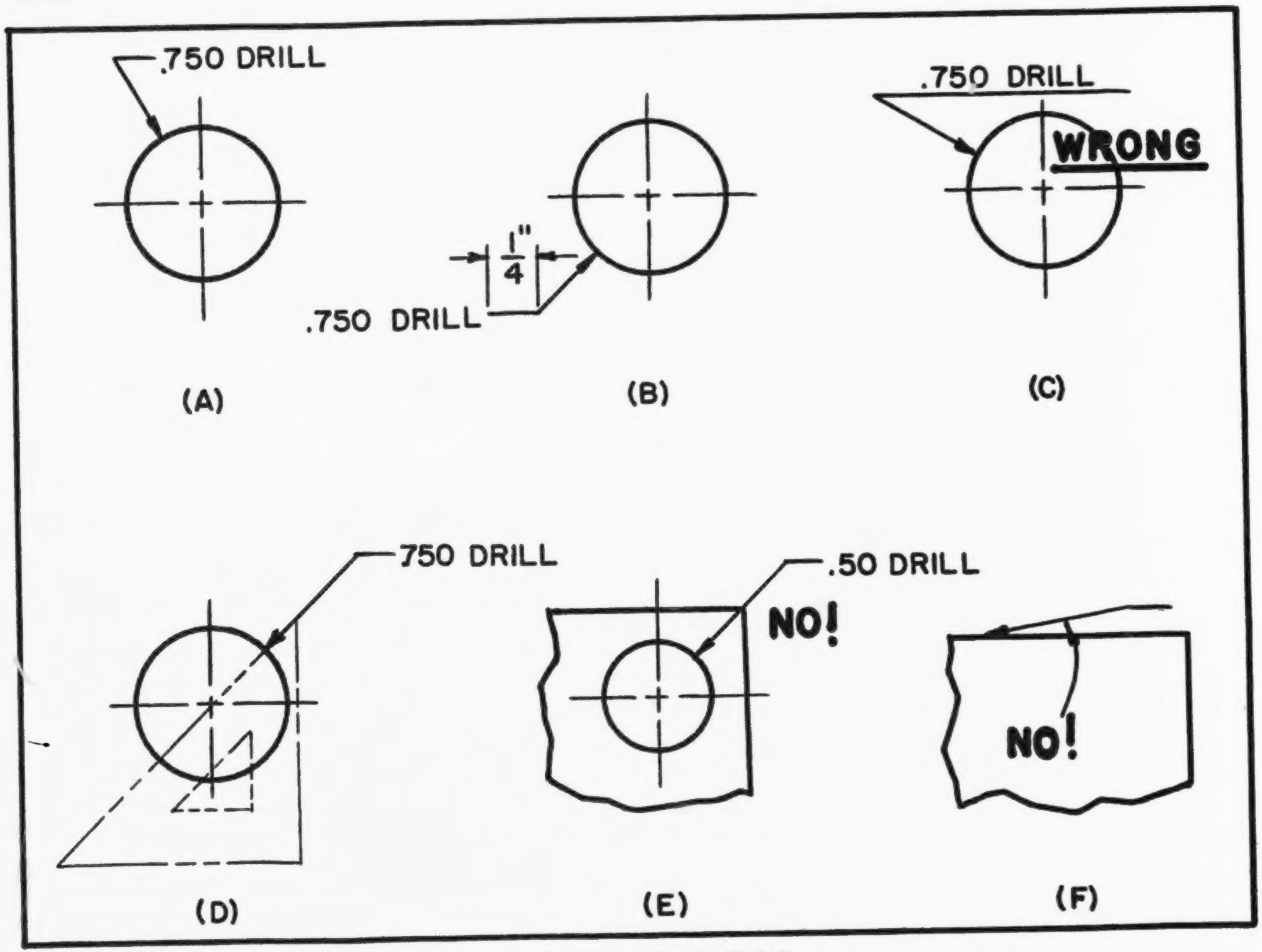
$\frac{1}{8}$"
1
2
1
2
1
2
3
(A)
(B)
(C)
(D)

ARROWHEADS

Figure 7.

ARROWHEADS, figure 7, indicate the extent of dimensions. They should be uniform in size and style throughout the drawing and not varied according to the size of the drawing or the length of dimensions. Make arrowheads about $\frac{1}{8}$" long and very narrow (a). Use strokes toward the point or away from the point as desired (b to d). The method at (b) is easier when the strokes are drawn toward the draftsman. For best appearance, fill in the arrowhead as at (d).

Leaders



.750 DRILL
$\frac{1}{4}$"
.750 DRILL
.750 DRILL
WRONG
(A)
(B)
(C)
750 DRILL
.50 DRILL
NO!
NO!
(D)
(E)
(F)

Figure 8. LEADERS

A LEADER (figure 8) is a thin solid line leading from a note or dimension and terminated by an arrowhead touching the part to which attention is directed (a). A leader should be an inclined straight line, if possible, except for the short horizontal "shoulder" (approx. $\frac{1}{4}$") extending from mid-height of the lettering AT THE BEGINNING OR END OF A NOTE (b). The shoulder is optional, but, if used, it should not be drawn so as to underline the lettering (c).

A leader to a circle should be radial, so that if extended it would pass through the center (d). A drawing presents a more pleasing appearance if leaders near each other are drawn parallel. Leaders should cross as few lines as possible and should never cross each other. They should not be drawn parallel to nearby lines of the drawing, allowed to pass through a corner of the view (e), drawn unnecessarily long, or drawn horizontally or vertically on the sheet. A leader should not be drawn at a small angle (f).

Fractional and Decimal Dimensions

When blueprinting came into use workmen in widely separated localities could use the same drawings, and it became the practice to dimension the drawings, more or less completely, in inches and common fractions, such as $\frac{1}{4}$", $\frac{1}{8}$", $\frac{1}{16}$", $\frac{1}{32}$", and $\frac{1}{64}$". The smallest dimension the workman was supposed to measure directly was $\frac{1}{64}$", which was the smallest division on the ordinary machinist's scale. When close fits were required, the drawing would carry a note such as "running fit" or "drive fit", and the workman would make considerably finer adjustment of size than $\frac{1}{64}$". Workmen were skilled, and it should not be thought that very accurate and excellent fits were not obtained. Hand-built machines were often beautiful examples of precision workmanship.

This system of units and common fractions is still used in architectural and structural work where close accuracy is relatively unimportant and where the steel tape or framing square is used to set off measurements.

Also today, there are many types of manufacturing in which units and common fractions are almost universally used because extreme accuracy is not necessary. An example of this is railway car drawing in which the structure is very large and extremely fine measurements are generally not required. However, there are also many small articles manufactured today in which the ordinary machinist's scale is sufficiently accurate, and units and common fractions for dimensions on drawings are considered perfectly satisfactory and suitable for the purpose.

Since it was cumbersome to use still smaller fractions such as $\frac{1}{128}$ or $\frac{1}{256}$, it became the practice to give decimal dimensions such as 4.2340, 3.815, etc., for dimensions requiring accuracy. Along with this, many of the dimensions such as pattern dimensions, forging dimensions, and relatively unimportant machine dimensions were still expressed in whole numbers and common fractions.

A given drawing today may be dimensioned entirely with whole numbers and common fractions, or entirely with decimals, or with a combination of the two. The last is the most common, especially with reference to machined castings or forgings in which the rough dimensions usually need not be closer than ± $\frac{1}{64}$". However, practice is rapidly moving toward the adoption of the complete decimal system for all dimensions.

On any drawing, decimal dimensions should be used wherever the degree of accuracy required is closer than ± $\frac{1}{64}$. For decimal equivalents of common fractions, see Appendix 1.

Complete Decimal System

The ever-increasing requirement for accuracy has brought greater use of decimals, while common fractions have been continued for dimensions that do not require great accuracy. The use of both common fractions and decimals on the same drawings has caused a great deal of confusion, and there is a definite trend toward the use of a complete decimal system for all dimensions. The metric system has many advantages, and undoubtedly would have been adopted if it had not been necessary to scrap all measuring devices in use and undergo the upheaval of making the change from the inch system.

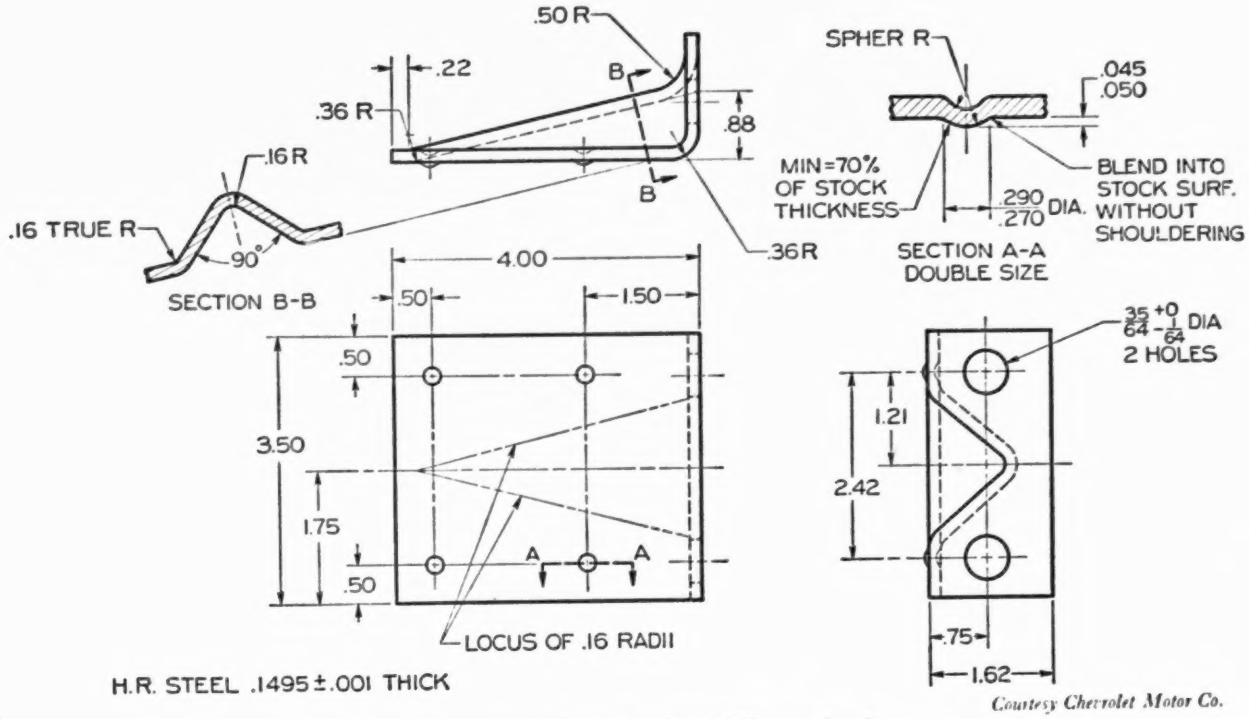
It was found that a decimal system based upon the inch as a unit of measure could assure most of the advantages of the metric system, and could be adopted by American industries without too much difficulty.

The ASA recommends the complete decimal system for optional use to replace common fractions. In this system, a two-place decimal is used when a common fraction is regarded as sufficiently accurate. When common fractions are replaced by decimals, computations are simplified as decimals can be added, subtracted, multiplied, or divided much more easily.

Two-place decimals are used when tolerance limits of ± .01 or more can be permitted. Three or more decimal places are used for tolerance limits of less than ± .01. In a two-place decimal, the second place preferably should be an even digit. For example, .02, .04, and .06 are preferred to .01, .03, or .05, so that when the dimension is divided by two, as is necessary in determining the radius from a diameter, the result will be a decimal of two places. However, odd two-place decimals are used when required for design purposes such as in dimensioning points on a smooth curve, or when strength or clearance is a factor.

In this system, common fractions may be continued to indicate nominal sizes of materials, drilled holes, punched holes, threads, keyways, and other standard features.

EXAMPLES: $\frac{1}{4}$-20UNC-2A; $\frac{5}{16}$ DRILL; STOCK $1\frac{1}{4} \times 1\frac{1}{2}$. If desired, decimals may be used for everything, including standard nominal sizes, such as .250-20UNC-2B or .750 HEX.


.50 R
.22
.36 R
B
B
.88
.16 R
.16 TRUE R
90°
SECTION B-B
.36R
SPHER R
.045
.050
MIN=70% OF STOCK THICKNESS
.290
.270 DIA.
BLEND INTO STOCK SURF. WITHOUT SHOULDERING
SECTION A-A DOUBLE SIZE
4.00
.50
1.50
.50
3.50
1.75
.50
A
A
LOCUS OF .16 RADII
$\frac{35}{64}{}^{+0}_{-\frac{1}{64}}$ DIA
2 HOLES
1.21
2.42
.75
1.62

H.R. STEEL .1495±.001 THICK

Courtesy Chevrolet Motor Co.

Complete Decimal Dimensioning.

Figure 9.

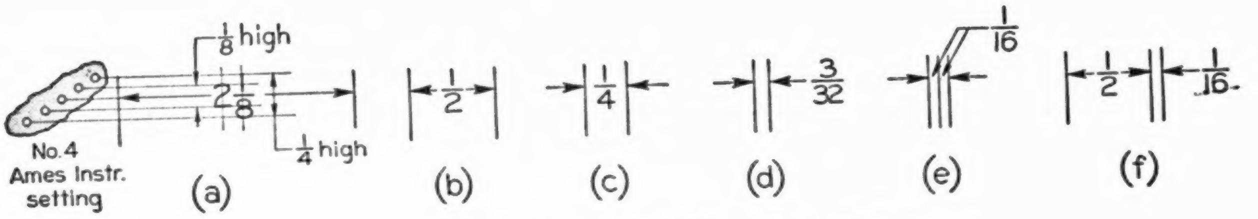
NOTE: For your classroom drawings, the tolerances to be specified in your title blocks will be 2PL ± .02, 3PL ± .005.

To round off a decimal value to a lesser number of places than that available: when the figure beyond the last figure to be retained is less than 5, the last figure should not be changed. For example, 3.46325, if cut off to three places, should be 3.463. When the figures beyond the last place to be retained amount to more than 5, the last figure retained should be increased by 1. For example, 8.37652, if cut off to three places, should be 8.377. When the figure beyond the last place to be retained is exactly 5 with only zeros following, the preceding number, if even, should be unchanged; if odd, it should be increased by 1. For example, 4.365 becomes 4.36 when cut off to two places. Also 4.355 becomes 4.36 when cut off to two places.

Shop scales and drafting scales for use in the complete decimal system are standardized by the ASA (ASA Z75.1-1955). The drafting scale is known as the DECIMAL SCALE.

Dimension Figures

The importance of good lettering of dimension figures cannot be overstated. The shop produces according to the directions on the drawing;and to save time and prevent costly mistakes, all lettering should be perfectly legible.

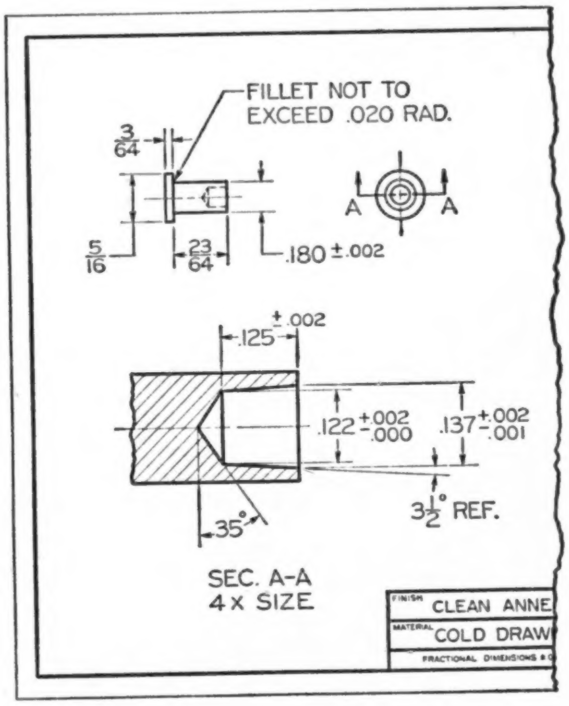

$\frac{1}{8}$ high
$2\frac{1}{8}$
$\frac{1}{4}$ high
No.4
Ames Instr.
setting
(a)
$\frac{1}{2}$
(b)
$\frac{1}{4}$
(c)
$\frac{3}{32}$
(d)
$\frac{1}{16}$
(e)
$\frac{1}{2}$
$\frac{1}{16}$
(f)

Common-Fraction Dimension Figures.

Figure 10.

As shown in figure 10(a), the standard height for whole numbers is $\frac{1}{8}$", and for fractions $\frac{1}{4}$". Students should use guide lines as shown in the figure. The numerator and denominator of a fraction should be clearly separated from the fraction bar. The fraction bar should always be horizontal. An exception to this may be made in crowded places, as in parts lists, but never in dimensioning.

Legibility should never be sacrificed by crowding dimension figures into limited spaces. For every such case there is a practical and effective method (figure 10a & b); there is enough space for the dimension line, the numeral, and the arrowheads. At (c) there is only enough room for the figure, and the arrowheads are placed outside. At (d) both the arrowheads and figure are placed outside. Other methods are shown at (e) and (f).


FILLET NOT TO
EXCEED .020 RAD.
$\frac{3}{64}$
$\frac{5}{16}$
$\frac{23}{64}$
.180 ±.002
A
A
.125 ±.002
.122 $^{+.002}_{-.000}$
.137 $^{+.002}_{-.001}$
35°
$3\frac{1}{2}$° REF.
SEC. A-A
4 X SIZE
FINISH CLEAN ANNE
MATERIAL COLD DRAW
FRACTIONAL DIMENSIONS

Removed Section.

Figure 11.

If necessary, a removed partial view may be drawn to an enlarged scale to provide the space needed for clear dimensioning (figure 11).

Methods of lettering decimal dimension figures are shown in figure 12. All numerals are $\frac{1}{8}$" high whether on one line or on two lines. As shown at (b), the space between lines of numerals is $\frac{1}{16}$", or $\frac{1}{32}$" on each side of the dimension line.

Make all decimal points bold, allowing ample space. Never letter a dimension figure over any line of the drawing.

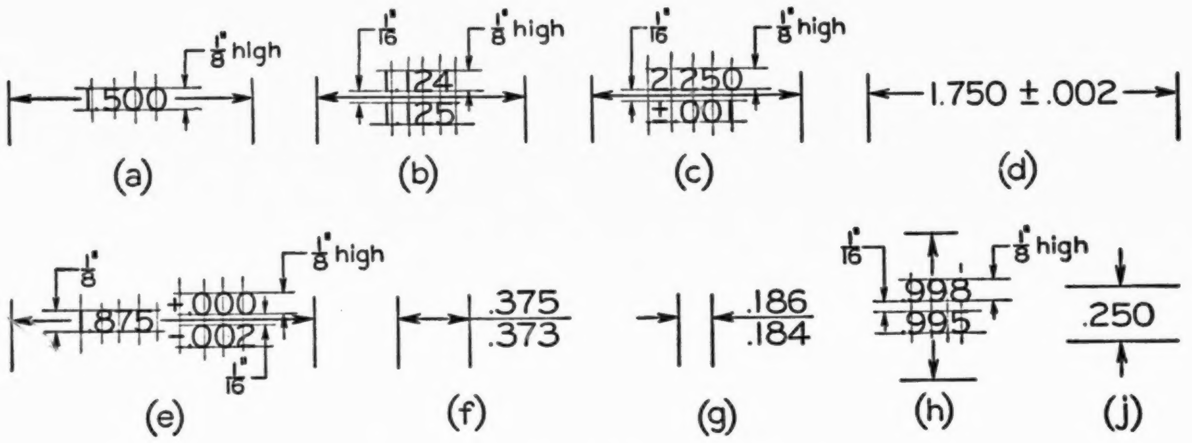
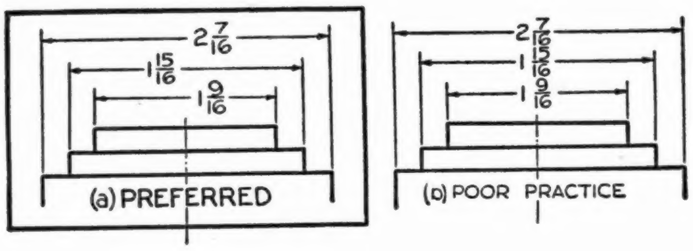

1/8" high
1.500
1/16"
1.124
1.125
2.250
±.001
1.750 ±.002
(a)
(b)
(c)
(d)
1/8"
1.875
+.000
-.002
.375
.373
.186
.184
.998
.995
.250
(e)
(f)
(g)
(h)
(j)

Figure 12. **Decimal Dimension Figures.**

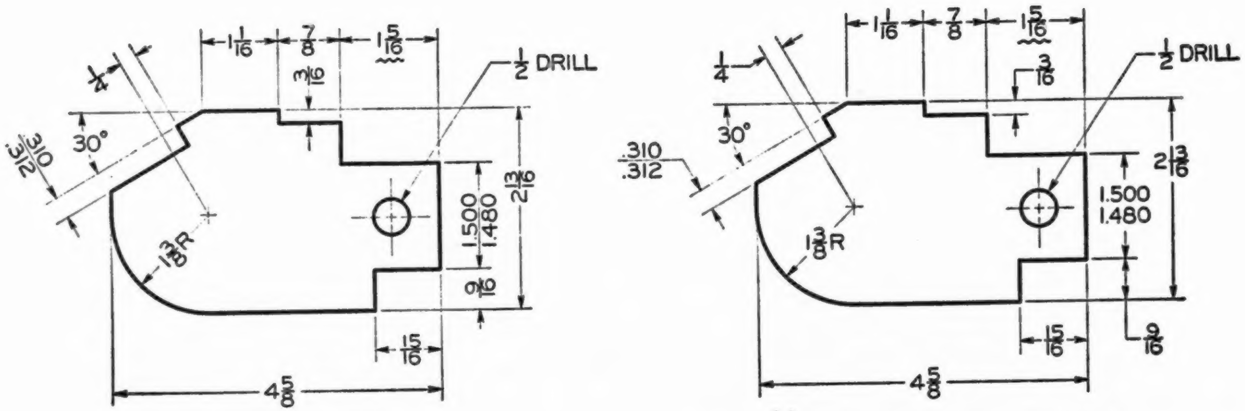

2 7/16
1 15/16
1 9/16
(a) PREFERRED
(b) POOR PRACTICE

In a group of parallel dimension lines, the numerals should be staggered as in figure 13(a), and not stacked up one above the other as at (b).

Figure 13. Staggering Dimensions.

Direction of Dimension Figures

Two systems of reading direction for dimension figures are approved by the ASA. In the ALIGNED SYSTEM (figure 14a) all dimension figures are aligned with the dimension lines so that they may be read from the bottom or from the right side of the sheet. Notes should always be lettered horizontally on the sheet.

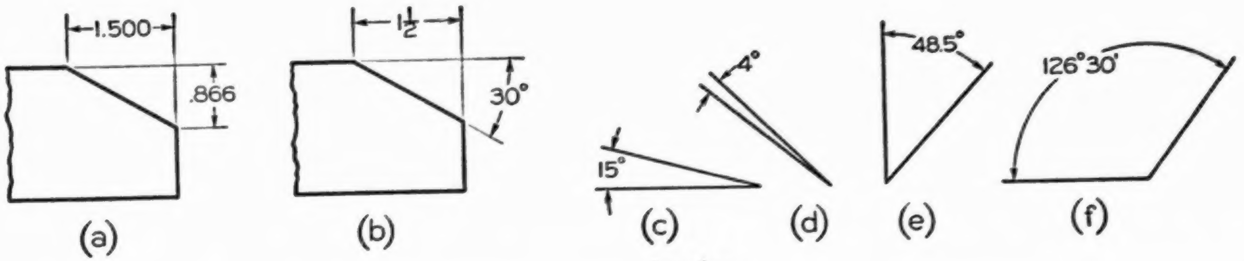

1/4
1 1/16
7/8
1 5/16
3/16
1/2 DRILL
30°
.310
.312
1 3/8 R
1.500
1.480
2 13/16
9/16
15/16
4 5/8

(a) ALIGNED SYSTEM (b) UNIDIRECTIONAL SYSTEM

Figure 14. **Directions of Dimension Figures.**

In the UNIDIRECTIONAL SYSTEM (figure 14b) all dimension figures and notes are lettered horizontally on the sheet. The unidirectional system has been extensively adopted in the aircraft, automotive, and other industries in which drawings are often very large and therefore hard to read from the side.

Dimensioning Angles



Angles.

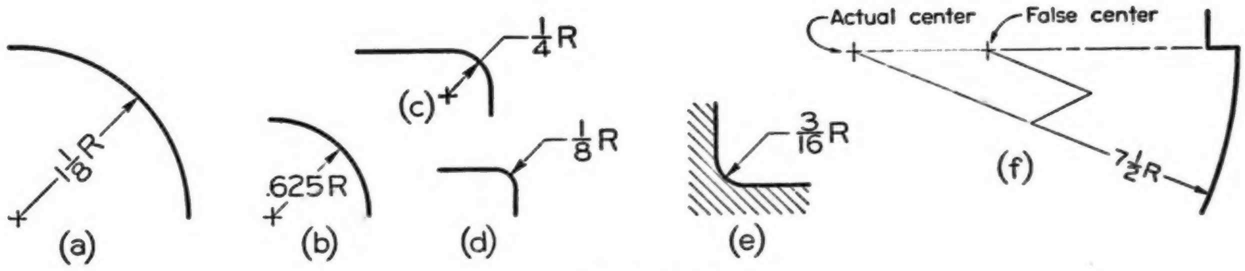
Figure 15.

Angles are dimensioned by means of coordinate dimensions of the two legs of a right triangle (figure 15a),or by means of a linear dimension and an angle in degrees (b).

The coordinate method is suitable for work requiring a high degree of accuracy. Variations of angle (in degrees) are hard to control because the amount of variation increases with the distance from the vertex of the angle. Methods of indicating various angles are shown from (c) to (f).

Dimensioning Arcs

A circular arc is dimensioned in the view in which its true shape is shown by giving the numeral denoting its radius,followed by the abbreviation "R",as shown in figure 16.



Dimensioning Arcs.

Figure 16.

Centers are indicated by small crosses except for small or unimportant radii. Crosses should not be drawn for undimensioned arcs. As shown at (a) and (b), when there is room enough, both the numeral and the arrowhead are placed inside the arc. At (c) the arrowhead is left inside, but the numeral had to be moved outside. At (d) both the arrowhead and the numeral had to be moved outside. At (e) is shown an alternate method to (c) or (d) to be used when section lines or other lines are in the way. Note that in the unidirectional system all of these numerals would be lettered horizontally on the sheet.

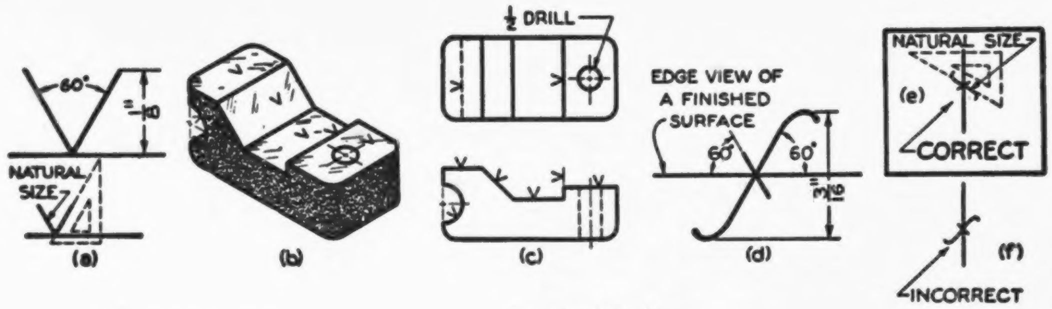
For a long radius as shown at (f) when the center falls outside the available space, the dimension line is drawn toward the actual center; but a false center may be indicated and the dimension line "jogged" to it as shown.

Fillets and Rounds

Individual fillets and rounds are dimensioned as any arc is, as shown in figure 16b-e. If there are only a few and they are obviously the same size, one typical radius is sufficient. However, fillets and rounds are often quite numerous on a drawing and most of them are likely to be some standard size, as $\frac{1}{8}$"R or $\frac{1}{4}$"R. In such cases, it is customary to give a note in the lower portion of the drawing to cover all such uniform fillets and rounds. Thus: FILLETS $\frac{1}{4}$R AND ROUNDS $\frac{1}{8}$R UNLESS OTHERWISE SPECIFIED, or ALL CASTING RADII $\frac{1}{4}$R UNLESS NOTED, or simply ALL FILLETS AND ROUNDS $\frac{1}{8}$R. The latter note is sufficient for your introductory working drawings.

Finish Marks

Two styles of finish marks are approved by the ASA, the newer "V" symbol and the older "f" symbol. The first (figure 17a) is like a capital "V", made about $\frac{1}{8}$" high in conformity with the dimension figures. For best results it should be drawn with the aid of the 30°-60° triangle.



Finish Marks.

Figure 17.

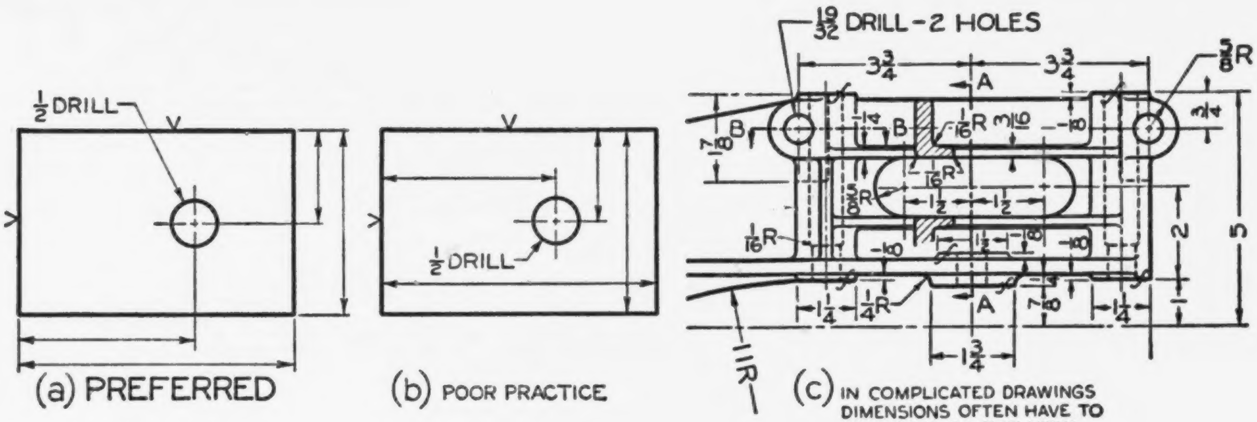
At (b) is shown a simple casting having several finished surfaces; and at (c) are shown two views of the same casting, showing how the finish marks are indicated on a drawing. THE FINISH MARK IS SHOWN ONLY ON THE EDGE VIEW OF A FINISHED SURFACE, AND IS REPEATED IN ANY OTHER VIEW IN WHICH THE SURFACE APPEARS AS A LINE, EVEN IF THE LINE IS A HIDDEN

LINE. The point of the V should point inward toward the body of metal in a manner similar to that of a tool bit. When it is necessary to control surface roughness of finished surfaces, the V is used as a base for the more elaborate surface quality symbols.

The old symbol "f" is still more widely used, though it is executed in a variety of forms. It is approved by the ASA in the form shown in figure 17d-e and will undoubtedly continue in use for many years. It is shown on the edge views of finished surfaces as described above for the V-type finish marks.

If a part is to be finished all over, finish marks should be omitted, and a general note should be lettered on the lower portion of the sheet, such as FINISH ALL OVER,or F.A.O.

Dimensions On or Off Views



(a) PREFERRED (b) POOR PRACTICE (c) IN COMPLICATED DRAWINGS DIMENSIONS OFTEN HAVE TO BE PLACED ON THE VIEW.

Dimensions On or Off the Views.

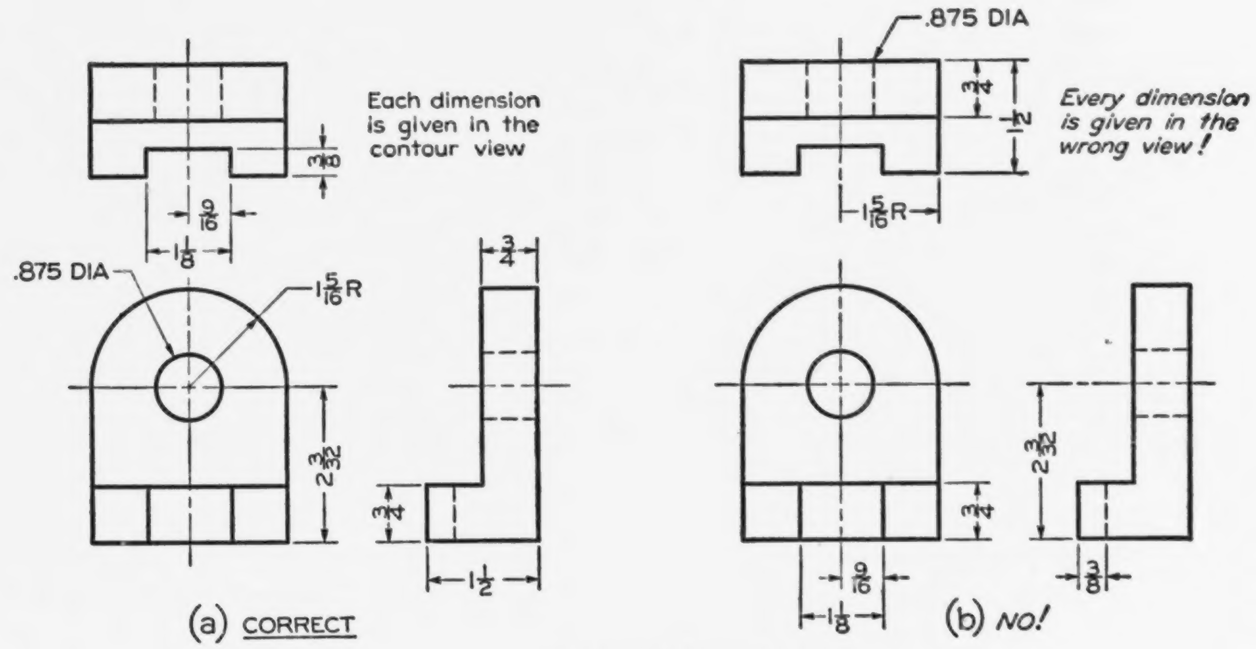
Figure 18.

DIMENSIONS SHOULD NOT BE PLACED UPON A VIEW UNLESS THE CLEARNESS OF THE DRAWING IS PROMOTED THEREBY. The ideal form is shown in figure 18a in which all dimensions are placed outside the view. Compare this with the evidently poor practice shown at (b). This is not to say that a dimension should never be placed on a view,-for in many cases, particularly in complicated drawings, this is necessary as shown at (c). Certain radii and other dimensions are given on the views, but in each case, investigation will reveal a good reason for placing the dimension on the view.

PLACE DIMENSIONS OUTSIDE OF VIEWS, EXCEPT WHERE DIRECTNESS OF APPLICATION AND CLARITY ARE GAINED BY PLACING THEM ON THE VIEWS WHERE THEY WILL BE CLOSER TO THE FEATURES DIMENSIONED.

Contour Dimensioning

Views are drawn to describe the shapes of the various features of the object, and dimensions are given to define exact sizes and locations of those shapes. It follows that DIMENSIONS SHOULD BE GIVEN WHERE THE SHAPES ARE SHOWN; that is, in the views where the contours are delineated as shown in figure 19a. Incorrect placement of the dimensions is shown at (b).


.875 DIA
$1\frac{5}{16}$R
$\frac{3}{8}$
$\frac{9}{16}$
$1\frac{1}{8}$
$2\frac{3}{32}$
$\frac{3}{4}$
$1\frac{1}{2}$
$\frac{1}{2}$

Each dimension is given in the contour view

Every dimension is given in the wrong view!

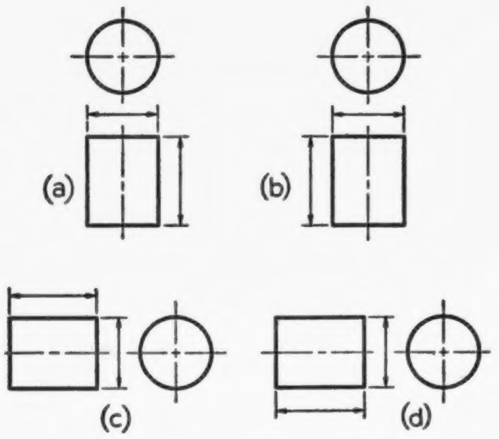
(a) CORRECT

(b) *NO!*

Contour Dimensioning.

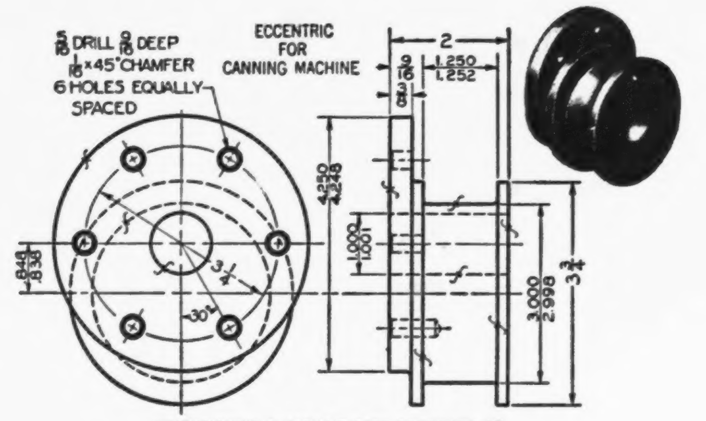
Figure 19.

If individual dimensions are attached directly to the contours that show the shapes being dimensioned, it will automatically prevent the attachment of dimensions to hidden lines, as shown for the depth $\frac{3}{8}$ of the slot at (b). It will also prevent the attachment of dimensions to a visible line, the meaning of which is not clear in a particular view, such as dimension $\frac{3}{4}$ for the height of the base at (b).



Dimensioning Cylinders.

Figure 20.

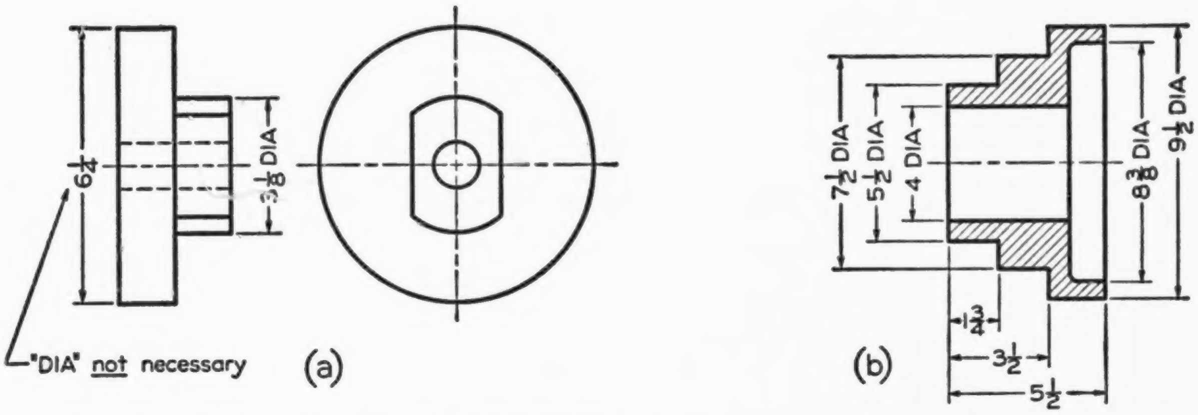

$\frac{5}{16}$ DRILL $\frac{9}{16}$ DEEP
$\frac{1}{16}$×45° CHAMFER
6 HOLES EQUALLY SPACED
ECCENTRIC FOR CANNING MACHINE
2
$\frac{9}{16}$
1.250
1.252
$\frac{3}{8}$
4.250
4.248
1.000
1.001
.848
.838
$3\frac{1}{4}$
30°
3.000
2.998
$3\frac{1}{4}$

DIMENSIONING A MACHINE PART COMPOSED OF CYLINDRICAL SHAPES

Dimensioning Cylinders.

Figure 21.

Although the placement of notes for holes follows the contour rule wherever possible as shown at (a), the diameter of an external cylindrical shape is preferably given in the rectangular view where it can be readily found near the dimension for the length of the cylinder, as shown in figures 20 and 21.



USE OF "DIA" TO INDICATE CIRCULAR SHAPE

USE OF "DIA" TO OMIT CIRCULAR VIEW

Figure 22. **Use of DIA in Dimensioning Cylinders.**

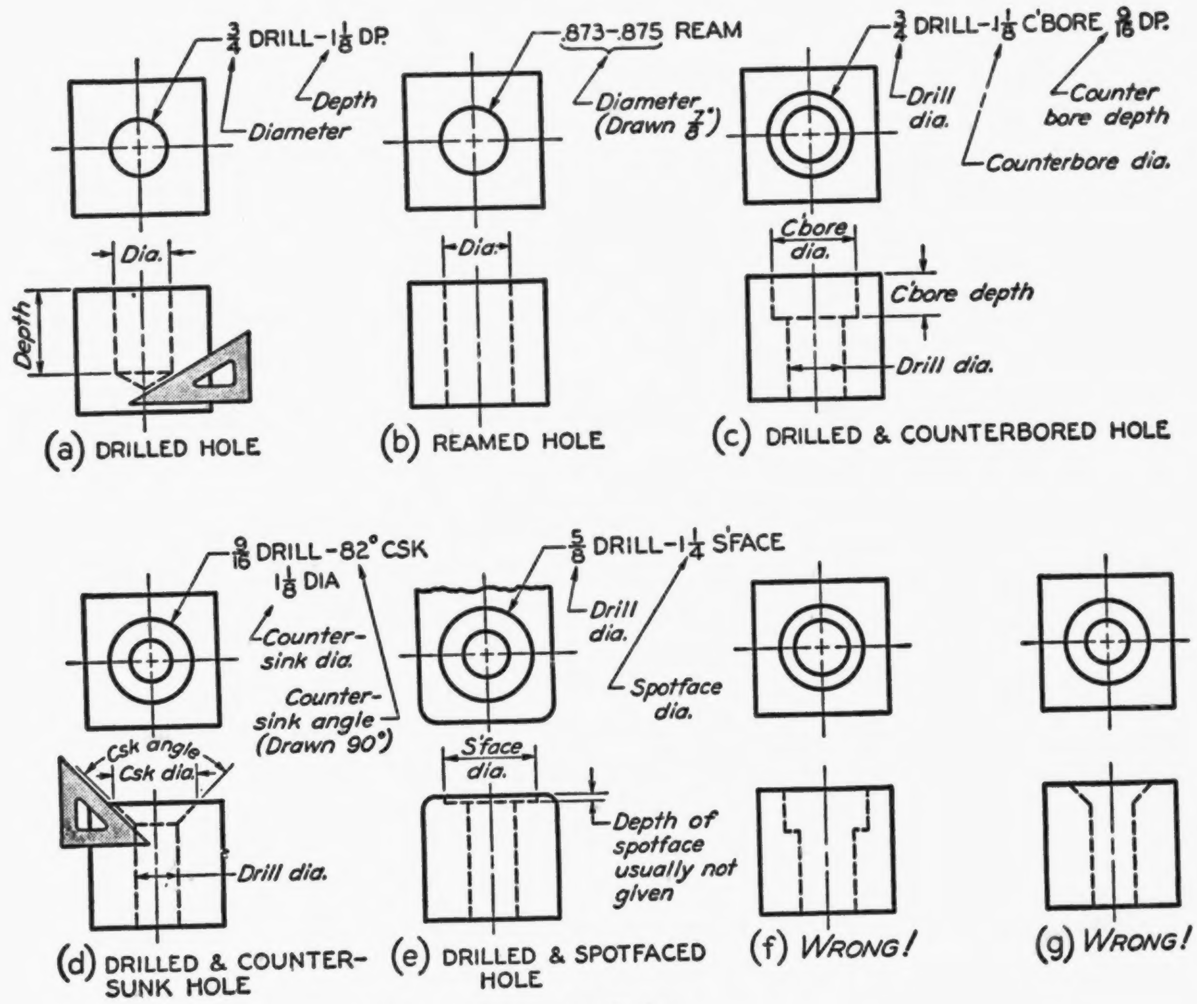
When it is not clear from the views that a dimension indicates a diameter, the abbreviation "DIA" should be given after the dimension figure (figure 22a). In some cases, "DIA" may be used to eliminate the circular view as shown in (b).

Size Dimensioning of Holes

Holes that are to be drilled, bored, reamed, punched, cored, etc., are usually specified by standard notes as shown in figure 23. The order of items in a note corresponds to the order of procedure in the shop in producing the hole. Two or more holes are dimensioned by a single note, the leader pointing to one of the holes as shown at the top of figure 24a.

As shown in figures 23 and 24, the leader of a note should, as a rule, point to the circular view of the hole. It should point to the rectangular view only when clearness is promoted. When the circular view of the hole has two or more concentric circles, as for counterbored, countersunk, or tapped holes, the arrowhead should touch the outer circle.

NOTES SHOULD ALWAYS BE LETTERED HORIZONTALLY ON THE PAPER, AND GUIDE LINES SHOULD ALWAYS BE USED.

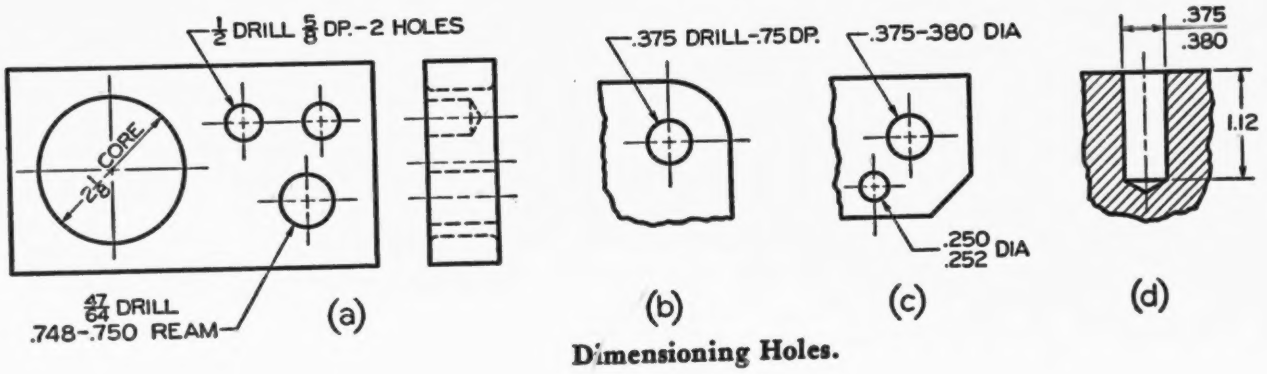

3/4 DRILL-1 1/8 DP.
Depth
Diameter
Dia.
Depth
.873-.875 REAM
Diameter (Drawn 7/8")
Dia.
3/4 DRILL-1 1/8 C'BORE 9/16 DP.
Drill dia.
Counter bore depth
Counterbore dia.
C'bore dia.
C'bore depth
Drill dia.
9/16 DRILL-82° CSK
1 1/8 DIA
Counter-sink dia.
Counter-sink angle (Drawn 90°)
Csk angle
Csk dia.
Drill dia.
5/8 DRILL-1 1/4 S'FACE
Drill dia.
Spotface dia.
S'face dia.
Depth of spotface usually not given

(a) DRILLED HOLE (b) REAMED HOLE (c) DRILLED & COUNTERBORED HOLE

(d) DRILLED & COUNTER-SUNK HOLE (e) DRILLED & SPOTFACED HOLE (f) *WRONG!* (g) *WRONG!*

How to Represent Holes.

Figure 23.


1/2 DRILL 5/8 DP.-2 HOLES
2 1/8 CORE
47/64 DRILL
.748-.750 REAM
.375 DRILL-.75 DP.
.375-380 DIA
.250
.252 DIA
.375
.380
1.12

(a) (b) (c) (d)

Dimensioning Holes.

Figure 24.

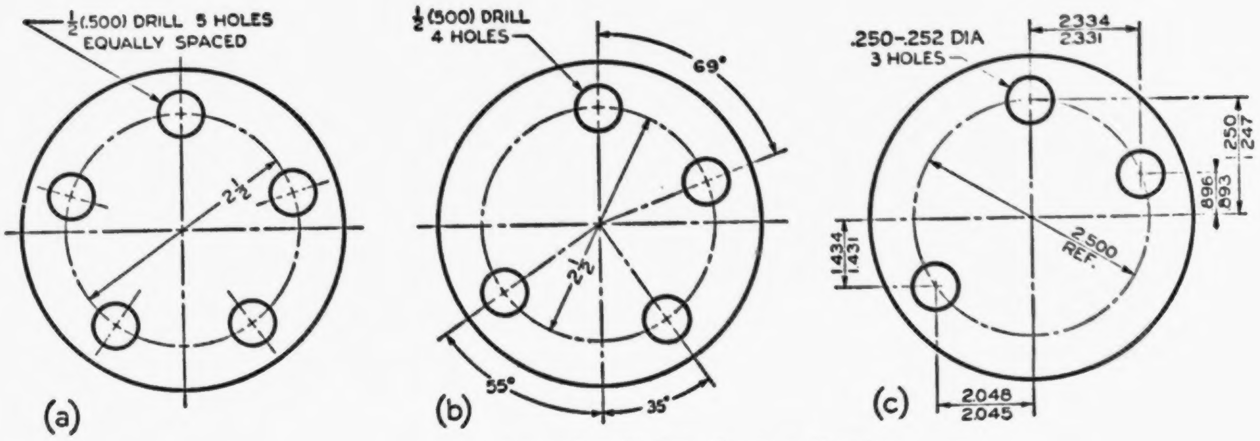
The use of decimal fractions instead of common fractions to designate drill sizes is encouraged. For numbered or letter-size drill, it is recommended that the decimal size be given in this manner or in parenthesis: #28 (.1405) DRILL or "P" (.3230) DRILL.

Location Dimensions

After the geometric shapes composing a structure have been dimensioned for SIZE, LOCATION DIMENSIONS must be given to show the relative positions of these geometric shapes. Rectangular shapes, whether in the form of solids or of recesses, are located with reference to their faces. Cylindrical or conical holes or bosses, or other symmetrical shapes, are located with reference to their center lines. Location dimensions for holes are preferably given in the circular view of the holes.

Location dimensions should lead to finished surfaces wherever possible because rough castings and forgings vary in size, and unfinished surfaces cannot be relied upon for accurate measurements. Of course, the STARTING DIMENSION used in locating the first machined surface on a rough casting or forging must necessarily lead from a rough surface, or from a center or a center line of the rough piece.

In general, location dimensions should be built from a finished surface as a starting plane, or from an important center or center line.



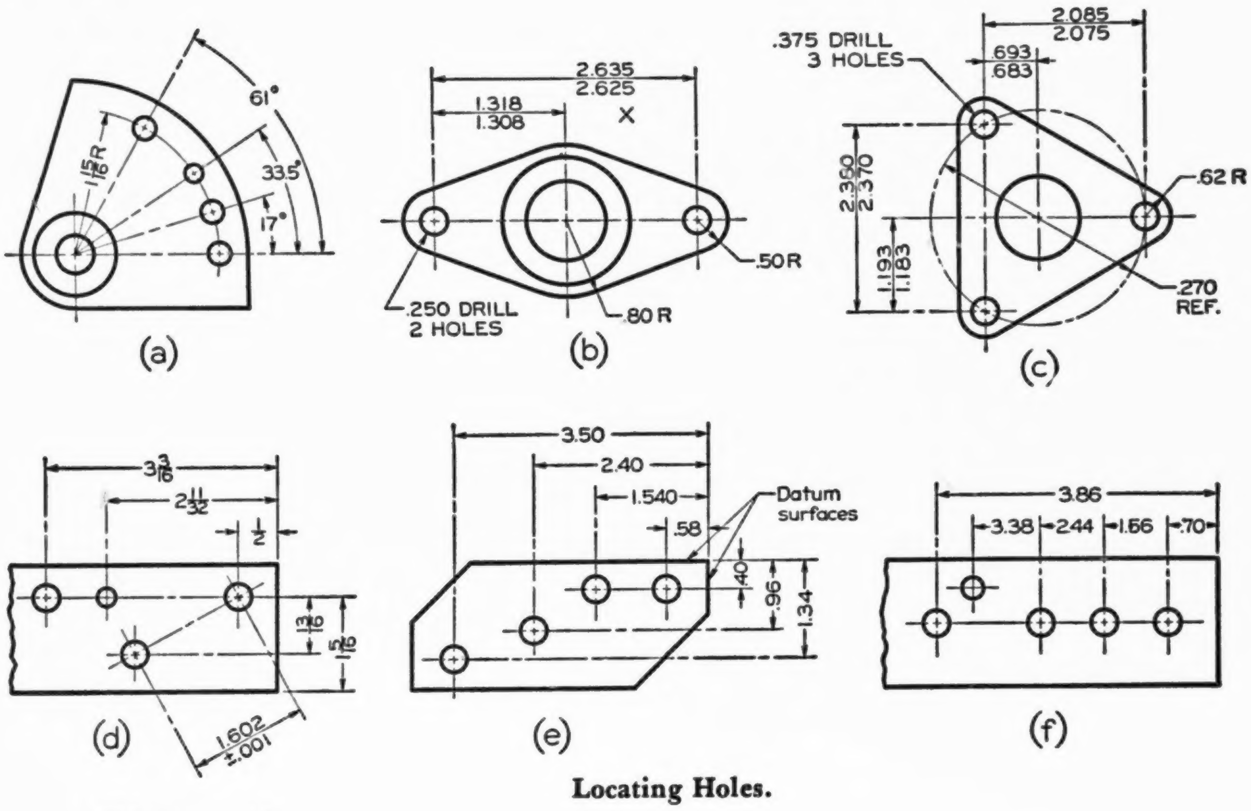
Locating Holes about a Center.

Figure 25.

Holes equally spaced about a common center may be dimensioned (figure 25) by giving the diameter (diagonally) of the CIRCLE OF CENTERS, or BOLT CIRCLE, and specifying "equally spaced" in the note.

Holes unequally spaced (b) are located by means of the bolt circle diameter plus angular measurements with reference to ONLY ONE of the center lines, as shown.

Where greater accuracy is required, coordinate dimensions should be given as at (c). In this case, the diameter of the bolt circle is marked "REF" to indicate that it is to be used only as a REFERENCE DIMENSION. Reference dimensions are given for information only. They are not intended to be measured and do not govern the shop operations. They represent calculated dimensions and are often useful in showing the intended design sizes. Figure 26 shows other examples.



61°
1 15/16 R
33.5°
17°
(a)
2.635
2.625
1.318
1.308
X
.50 R
.250 DRILL
2 HOLES
.80 R
(b)
2.085
2.075
.375 DRILL
3 HOLES
.693
.683
2.360
2.370
1.193
1.183
.62 R
.270
REF.
(c)
3 3/16
2 11/32
1/2
13/16
1 5/16
1.602
±.001
(d)
3.50
2.40
1.540
.58
Datum
surfaces
.40
.96
1.34
(e)
3.86
3.38
2.44
1.66
.70
(f)

Locating Holes.

Figure 26.

Superfluous Dimensions

Although it is necessary to give all dimensions, the draftsman should avoid giving unnecessary or superfluous dimensions (figure 27). Dimensions should not be repeated on the same view or on different views, nor should the same information be given in two different ways.

In figure 27(2) is shown a type of superfluous dimensioning that should generally be avoided, especially in machine drawing where accuracy is important. The workman should not be allowed a choice between two dimensions. AVOID "CHAIN" DIMENSIONING where an overall dimension accompanies a complete series of detail dimensions. One dimension in the chain should be omitted. This is especially true in tolerance dimensioning.

Some inexperienced draftsmen omit both end dimensions in a chain, such as those at the right at (2), assuming that the holes will be understood to be centered. One of the two location dimensions must be given.

As shown at (5) when it is clear that one dimension applies to several identical features, it need not be repeated. This applies generally to fillets and rounds and other non-critical features.

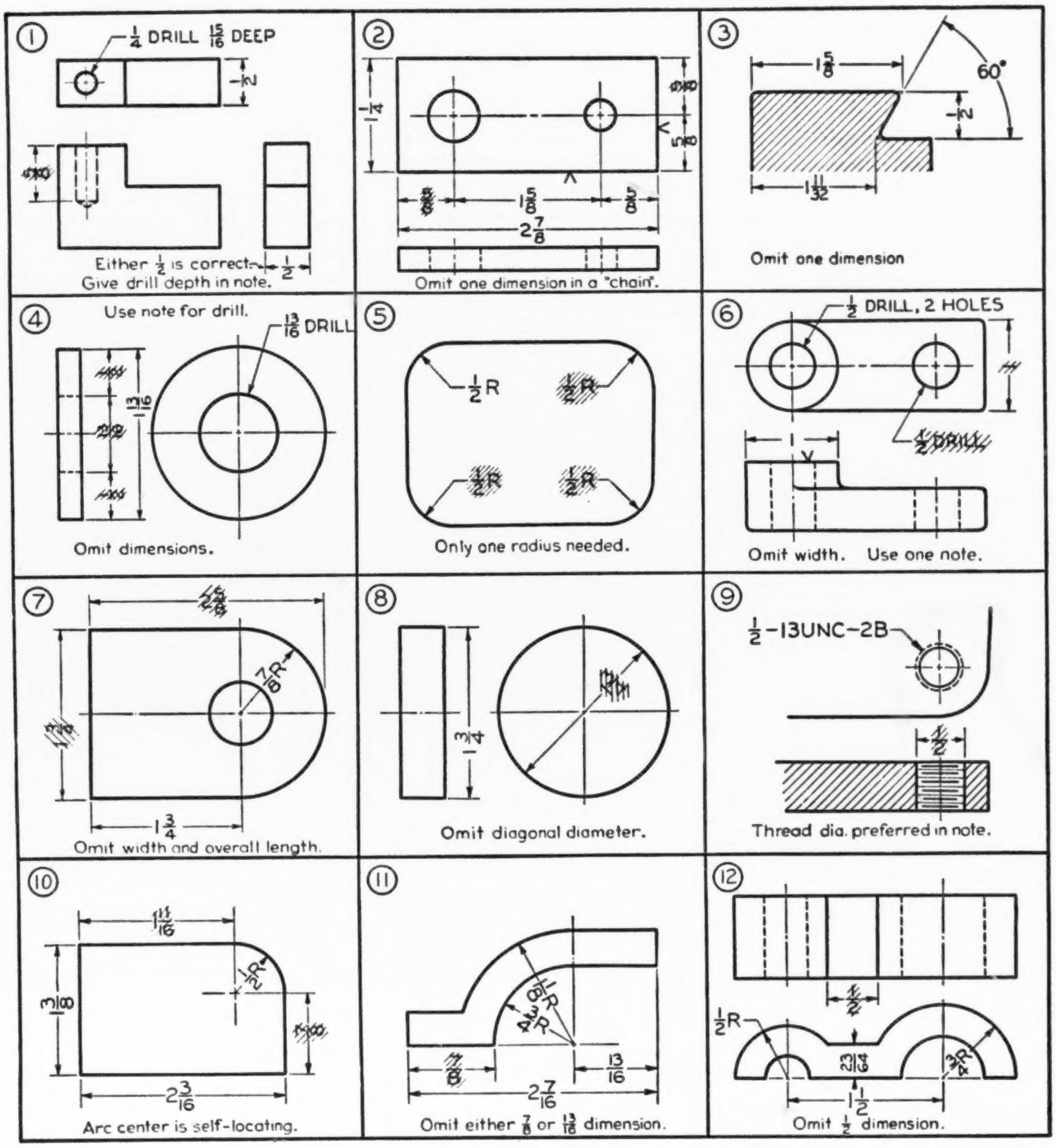

①
¼ DRILL 15/16 DEEP
½
Either ½ is correct.
Give drill depth in note.
②
1¼
5/8
1 5/8
2 7/8
Omit one dimension in a "chain".
③
1 5/8
60°
½
1 11/32
Omit one dimension
④
Use note for drill.
13/16 DRILL
1 13/16
Omit dimensions.
⑤
½R
Only one radius needed.
⑥
½ DRILL, 2 HOLES
1
Omit width. Use one note.
⑦
7/8R
1 3/4
Omit width and overall length.
⑧
1 3/4
Omit diagonal diameter.
⑨
½-13UNC-2B
Thread dia. preferred in note.
⑩
1 11/16
3 1/8
½R
2 3/16
Arc center is self-locating.
⑪
13/16
2 7/16
Omit either 7/8 or 13/16 dimension.
⑫
½R
23/64
3/4R
1½
Omit ½ dimension.

Figure 27. **Superfluous Dimensions.**

Notes

It is usually necessary to supplement the direct dimensions with notes (figure 28). They should be brief and should be carefully worded so as to be capable of only one interpretation. NOTES SHOULD ALWAYS BE

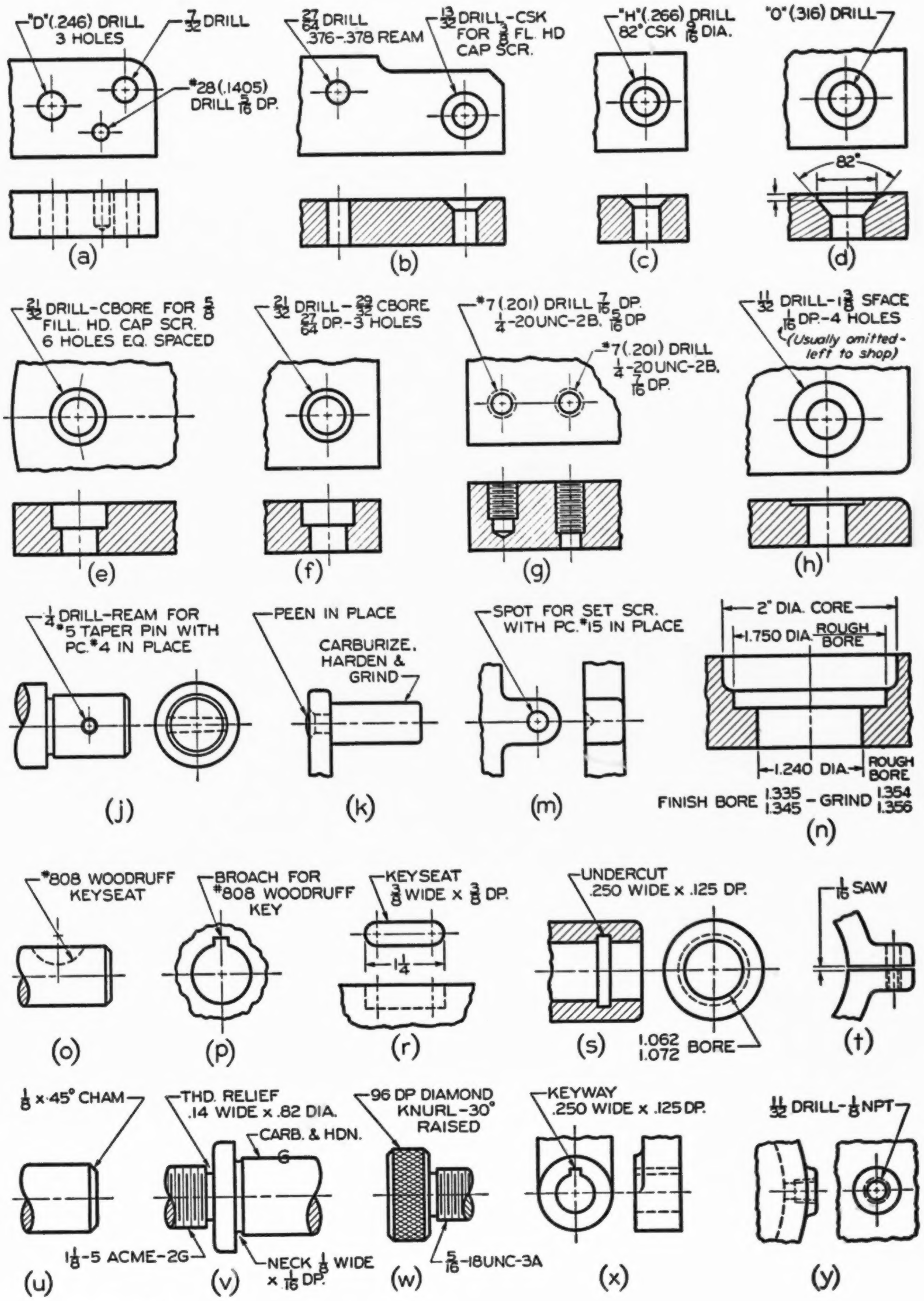

"D"(.246) DRILL 3 HOLES
7/32 DRILL
*28(.1405) DRILL 5/16 DP.
(a)
27/64 DRILL .376-.378 REAM
13/32 DRILL-CSK FOR 3/8 FL. HD CAP SCR.
(b)
"H"(.266) DRILL 82° CSK 9/16 DIA.
(c)
"O"(316) DRILL
82°
(d)
21/32 DRILL-CBORE FOR 5/8 FILL. HD. CAP SCR. 6 HOLES EQ. SPACED
(e)
21/32 DRILL-29/32 CBORE 27/64 DP.-3 HOLES
(f)
*7(.201) DRILL 7/16 DP. 1/4-20UNC-2B. 5/16 DP
*7(.201) DRILL 1/4-20UNC-2B. 7/16 DP.
(g)
11/32 DRILL-1 3/8 SFACE 1/16 DP.-4 HOLES
(Usually omitted-left to shop)
(h)
1/4 DRILL-REAM FOR *5 TAPER PIN WITH PC.*4 IN PLACE
(j)
PEEN IN PLACE
CARBURIZE, HARDEN & GRIND
(k)
SPOT FOR SET SCR. WITH PC.*15 IN PLACE
(m)
2" DIA. CORE
1.750 DIA. ROUGH BORE
1.240 DIA. ROUGH BORE
FINISH BORE 1.335 1.345 - GRIND 1.354 1.356
(n)
*808 WOODRUFF KEYSEAT
(o)
BROACH FOR *808 WOODRUFF KEY
(p)
KEYSEAT 3/8 WIDE x 3/8 DP.
1 1/4
(r)
UNDERCUT .250 WIDE x .125 DP.
1.062 1.072 BORE
(s)
1/16 SAW
(t)
1/8 x 45° CHAM
1 1/8-5 ACME-2G
(u)
THD. RELIEF .14 WIDE x .82 DIA.
CARB. & HDN.
G
NECK 1/8 WIDE x 1/16 DP.
(v)
96 DP DIAMOND KNURL-30° RAISED
5/16-18UNC-3A
(w)
KEYWAY .250 WIDE x .125 DP.
(x)
11/32 DRILL-1/8 NPT
(y)

Figure 28. Dimensioning Notes.

LETTERED HORIZONTALLY ON THE SHEET WITH GUIDE LINES AND ARRANGED IN A SYSTEMATIC MANNER. They should not be lettered in crowded places. Avoid placing notes between views if possible. They should not be lettered closely enough to each other to confuse the reader,or close enough to another view or detail to suggest application to the wrong place. Leaders should be as short as possible and cross as few lines as possible. They should never run through a corner of a view or through any specific points or intersections.

Notes are classified as GENERAL NOTES when they apply to an entire drawing, or LOCAL NOTES when they apply to specific items.

GENERAL NOTES. General notes should be lettered in the lower right-hand corner of the drawing above, or to the left of the title block, or in a central position below the view to which they apply; e.g., FINISH ALL OVER, BREAK SHARP EDGES TO $\frac{1}{32}$R, SAE 3345-BRINELL 340-380, or ALL DRAFT ANGLES 3° UNLESS OTHERWISE SPECIFIED, or DIMENSIONS APPLY PLATING. In machine drawings, the title strip or title block will carry many general notes including material, general tolerances, heat treatment, pattern information, etc.

LOCAL NOTES. Local notes apply to specific operations only,and are connected by a leader to the point at which such operations are performed; e.g., $\frac{1}{4}$ DRILL-4 HOLES; $\frac{1}{16}$ x 45° CHAMFER; or 33p. DIAMOND KNURL, RAISED. The leader should be attached at the front of the first word of a note,or just after the last word,and not at any intermediate place.

Certain commonly used abbreviations may be used freely in notes, such as "THD", "DIA", "MAX", etc. The less common abbreviations should be avoided as much as possible. All abbreviations should conform to ASA Z32.13-1950. See Appendix #2 for American Standard abbreviations.

In general, leaders and notes should not be placed on the drawing until the dimensioning is substantially completed. If notes are lettered first, it will be found almost invariably that they will be in the way of necessary dimensions and will have to be moved.

Dimensioning of Threads

Local notes are used to specify dimensions of threads. For tapped holes the notes should, if possible, be attached to the circular views of the holes as shown in figure 28g. For external threads, the notes are usually placed in the longitudinal views where the threads are more easily recognized as at (v) and (w). More detail is provided in lesson 4 on Threads and Fasteners.

Dimensioning of Chamfers

A CHAMFER is a beveled or sloping edge. When the angle is not 45° it is dimensioned by giving the length and the angle as in figure 29a.

A 45° chamfer also may be dimensioned in a manner similar to that shown at (a), but usually it is dimensioned by note as at (b).

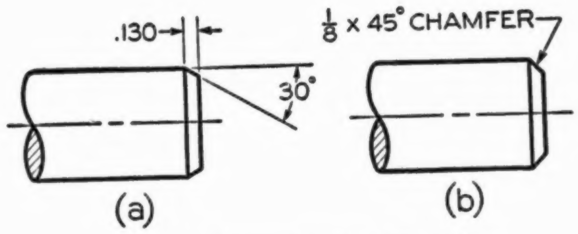

.130
30°
$\frac{1}{8}$ x 45° CHAMFER
(a)
(b)

Figure 29.

Dimensioning Chamfers.

Shaft Centers

Shaft centers are required on shafts, spindles, and other conical or cylindrical parts for turning, grinding, and other operations. Such a center may be dimensioned as shown in figure 30. Normally the centers are produced by a combined drill and countersink.

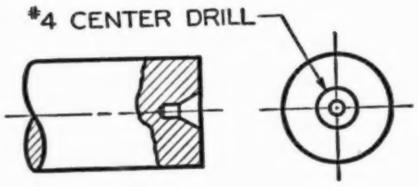

#4 CENTER DRILL

Figure 30.

Shaft Center.

Dimensioning Keyways

Methods of dimensioning keyways for Woodruff keys and stock keys are shown in figure 31. Note, in both cases, the use of a dimension to center the keyway in the shaft or collar. The preferred method of dimensioning the depth of a keyway is to give the dimension from the bottom of the keyway to the opposite side of the shaft or hole as shown. The method of computing such a dimension is shown at (d). Values for A may be found in machinists' hand books.

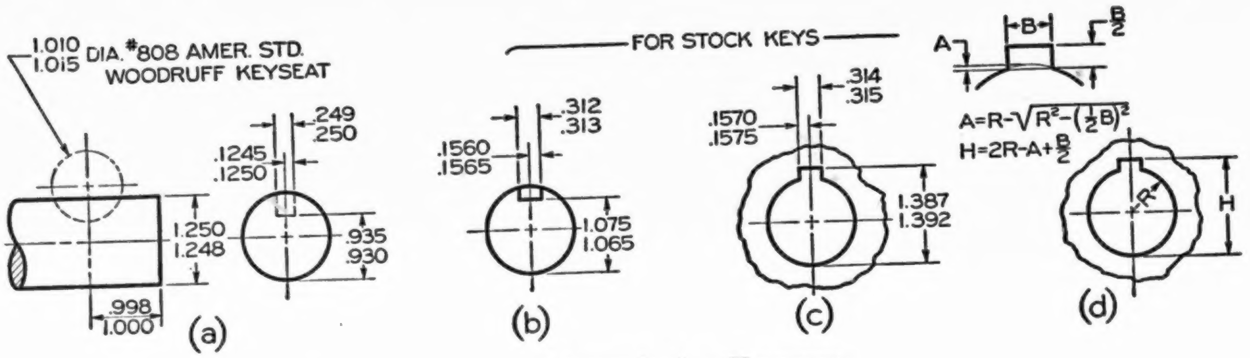
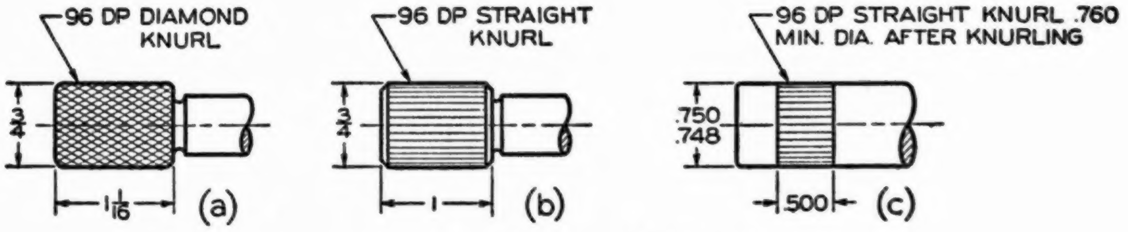

1.010
1.015 DIA. #808 AMER. STD.
WOODRUFF KEYSEAT
.249
.250
.1245
.1250
1.250
1.248
.935
.930
.998
1.000
(a)
FOR STOCK KEYS
.312
.313
.1560
.1565
1.075
1.065
(b)
.314
.315
.1570
.1575
1.387
1.392
(c)
A
B
$\frac{B}{2}$
$A=R-\sqrt{R^2-(\frac{1}{2}B)^2}$
$H=2R-A+\frac{B}{2}$
R
H
(d)

Figure 31.

Dimensioning Keyways.

Dimensioning Knurls

A KNURL is a roughened surface to provide a better hand grip or to be used for a press fit between two parts. For hand-gripping purposes, it is necessary only to give the pitch of the knurl, the type of knurling, and the length of the knurled area (figure 32a-b). To dimension a knurl for a press fit, the toleranced diameter before knurling should be given (c). A note should be added giving the pitch and type of knurl and the minimum diameter after knurling.



Dimensioning Knurls.

Figure 32.

Do's and Don'ts of Dimensioning

The following checklist summarizes briefly most of the situations in which a beginning draftsman is likely to make a mistake in dimensioning. The student should check his drawing by this list before submitting it to his instructor.

1. Each dimension should be given clearly so that it can be interpreted in only one way.
2. Dimensions should not be duplicated or the same information be given in two different ways, and no dimensions should be given except those needed to produce or inspect the part.
3. Dimensions should be given between points or surfaces which have a functional relation to each other or which control the location of mating parts.
4. Dimensions should be given to finished surfaces or important center lines in preference to rough surfaces wherever possible.
5. Dimensions should be so given that it will not be necessary for the machinist to calculate, scale, or assume any dimension.
6. Dimensions should be attached to the view where the shape is best shown (contour rule).
7. Dimensions should be placed in the views where the features dimensioned are shown true size.
8. Avoid dimensioning to hidden lines wherever possible.
9. Dimensions should not be placed upon a view unless clearness is promoted thereby.
10. Dimensions applying to two adjacent views should be placed between views unless clearness is promoted by placing them outside.

11. The longer dimensions should be placed outside all intermediate dimensions so that dimension lines will not cross extension lines.
12. In machine drawing, omit all inch marks except where necessary for clearness; e.g., 1" Valve.
13. Do not expect the workman to assume a feature is centered (as a hole on a plate), but give a location dimension from one side. However, if a hole is to be centered on a symmetrical rough casting, mark the center line C, and omit the locating dimension from the center line.
14. A dimension should be attached to only one view (extension lines not connecting two views).
15. Detail dimensions should "line up" in chain fashion.
16. Avoid a complete chain of detail dimensions; rather, omit one, otherwise one detail dimension or the overall dimension should be marked "REF."
17. A dimension line should never be drawn through a dimension figure. A figure should never be lettered over any line of the drawing.
18. Dimension lines should be spaced uniformly throughout the drawing. They should be at least $\frac{3}{8}$" from the object outline and $\frac{1}{4}$" apart.
19. No line of the drawing should be used as a dimension line or coincide with a dimension line.
20. A dimension line should never be joined end-to-end (chain fashion) with any line of the drawing.
21. Dimension lines and extension lines should not cross, if avoidable.
22. When extension lines cross extension lines or visible lines, no break in either line should be made.
23. A center line may be extended and used as an extension line in which case it is still made like a center line.
24. Center lines should generally not extend from view to view.
25. Leaders for notes should be straight, not curved, and pointing to the circular views of holes wherever possible.
26. Leaders should slope at 45°, 30°, or 60° with the horizontal, but may be made at any odd angle except vertical or horizontal.
27. Leaders should extend from the beginning or end of a note, the horizontal "shoulder" extending from the mid-height of the lettering.
28. Dimension figures should be approximately centered between the arrowheads except that, in a "stack" of dimensions, the figures should be "staggered."
29. Dimension figures should be about $\frac{1}{8}$" high for whole numbers and $\frac{1}{4}$" high for fractions.
30. Dimension figures should never be crowded or in any way made difficult to read.

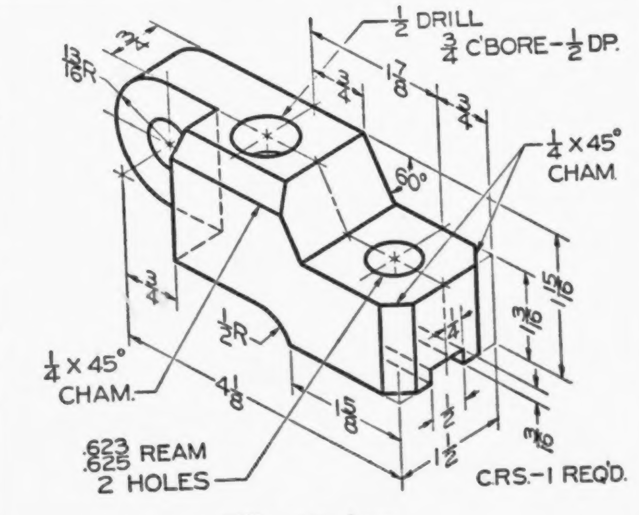
31. Dimension figures should not be lettered over sectioned areas unless necessary, in which case a clear space should be left for the dimension figures.
32. Dimension figures for angles should be lettered horizontally.
33. Fraction bars should always be parallel to the dimension lines, never inclined.
34. The numerator and denominator of a fraction should never touch the fraction bar.
35. Notes should always be lettered horizontally on the sheet.
36. Notes should be brief and clear, and the wording should be standard in form.
37. Finish marks should be placed on the edge views of all finished surfaces, including hidden edges and the contour and circular views of cylindrical surfaces.
38. Finish marks should be omitted on holes or other features where a note specifies a machining operation.
39. Finish marks should be omitted on parts made from rolled stock.
40. If a part is finished all over, omit all finish marks and use the general note: FINISH ALL OVER, or F.A.O.
41. A cylinder is dimensioned by giving both its diameter and length in the rectangular view, except when notes are used for holes. A diagonal diameter in the circular view may be used in cases where clearness is gained thereby.
42. Holes to be bored, drilled, reamed, etc., are size-dimensioned by notes in which the leaders preferably point toward the circular view of the holes. Indications of shop processes may be omitted from notes.
43. Drill sizes are preferably expressed in decimals. Particularly for drills designated by number of letter, the decimal size must also be given.
44. In general, a circle is dimensioned by its diameter and an arc by its radius.
45. Avoid diagonal diameters except for very large holes and for circles of centers. They may be used on positive cylinders when clearness is gained thereby.
46. A diameter dimension figure should be followed by "DIA" except when it is obviously a diameter.
47. A radius dimension figure should always be followed by the letter "R". The radial dimension line should have only one arrowhead, and it should touch the arc.
48. Cylinders should be located by their center lines.
49. Cylinders should be located in the circular views, if possible.

50. Cylinders should be located by coordinate dimensions in preference to angular dimensions where accuracy is important.
51. When there are several rough non-critical features obviously the same size (fillets, rounds, ribs, etc.), it is necessary to give only typical dimensions, or to use a note.
52. When a dimension is not to scale, it should be underscored with a wavy line, or marked "NTS" or "NOT TO SCALE."
53. Mating dimensions should be given correspondingly on drawings of mating parts.
54. Pattern dimensions should be given in common whole numbers and fractions to the nearest $\frac{1}{16}$".
55. Decimal dimensions should be used when greater accuracy than $\frac{1}{64}$" is required on a machine dimension.
56. Avoid cumulative tolerances, especially in limit dimensioning.

ASSIGNMENT:

In drawing the following problems, include all dimensions and necessary notes. Begin now to develop good line quality, dimension spacing techniques, and completeness of thought concerning each problem. The material specification and necessary notes are included for the most part on the problem sketches.

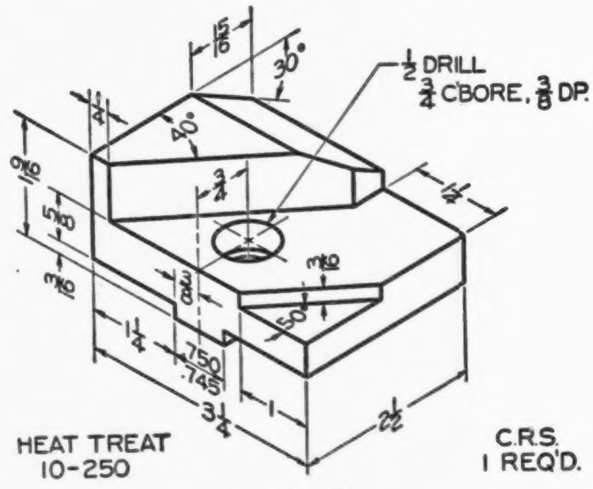
Use size B paper, using the working drawing title block form. Not all of the following may be required. Give attention to the instructor's directions.



1/2 DRILL
3/4 C'BORE-1/2 DP.
13/16R
3/4
3/4
1 7/8
3/4
1/4 x 45°
CHAM.
60°
15/16
3/16
1/4
3/4
1/2R
1/4 x 45°
CHAM.
4 1/8
1 5/8
1/2
1 1/2
3/16
.623
.625 REAM
2 HOLES
C.R.S.-1 REQ'D.

Vibrator Arm

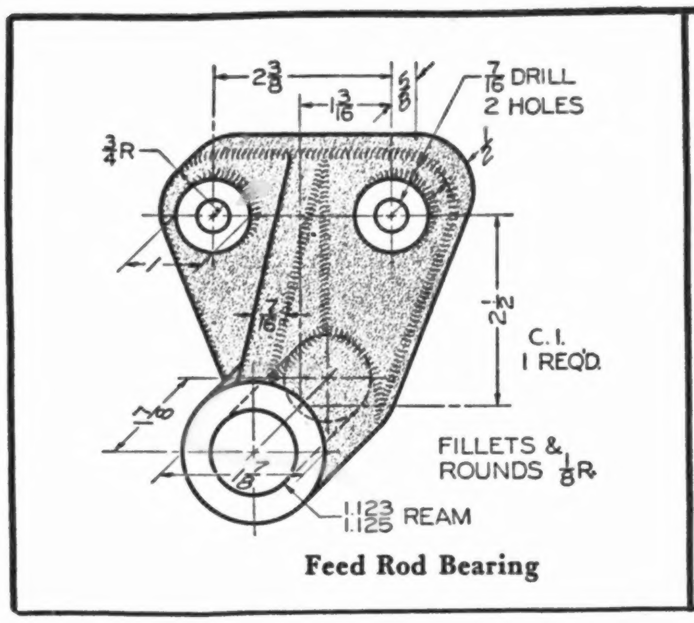
Problem 1.



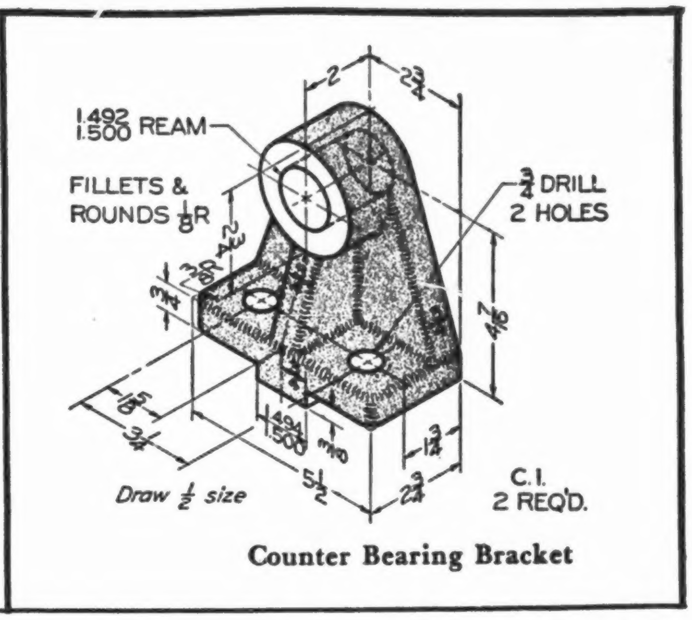
15/16
30°
1/2 DRILL
3/4 C'BORE, 3/8 DP.
1/4
40°
9/16
3/4
5/16
3/16
3/16
3/8
1 1/4
.50
1 1/4
.750
.745
3 1/4
1
2 1/2
HEAT TREAT
10-250
C.R.S.
1 REQ'D.

Index Feed

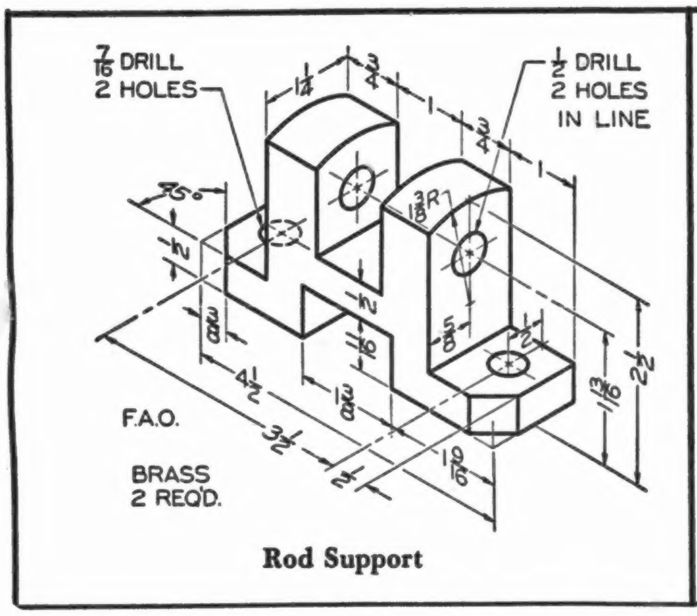
Problem 2.


2 3/8
1 3/16
5/8
7/16 DRILL
2 HOLES
3/4 R
1/2
1
7/16
2 1/2
C. I.
1 REQ'D.
1 7/8
7/8
FILLETS &
ROUNDS 1/8 R.
1.123
1.125 REAM
Feed Rod Bearing

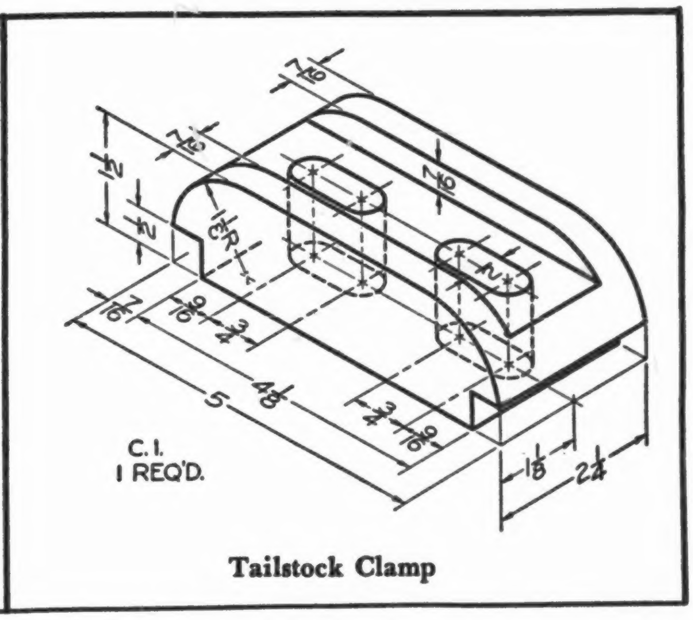
Problem 3.


2
2 3/4
1.492
1.500 REAM
FILLETS &
ROUNDS 1/8 R
3/4 DRILL
2 HOLES
7 1/16
3/4
5/8
3 1/4
1.494
1.500
5 1/2
2 3/4
1 3/4
Draw 1/2 size
C.I.
2 REQ'D.
Counter Bearing Bracket

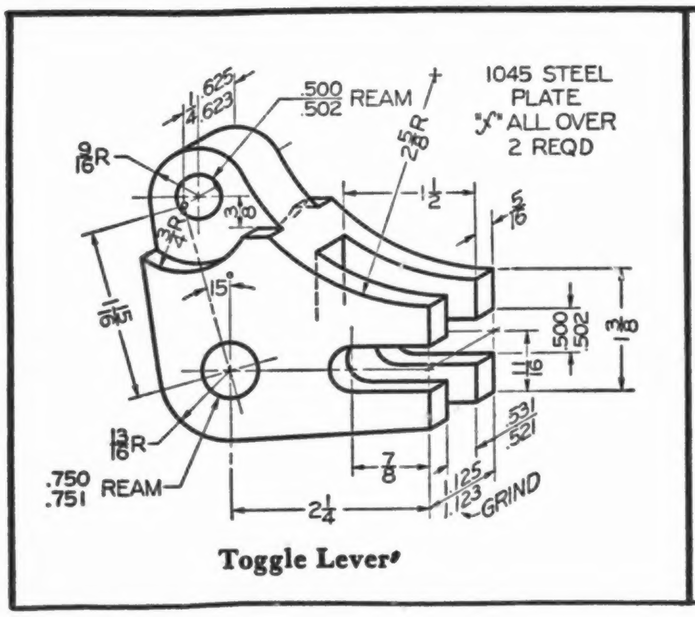
Problem 4.


7/16 DRILL
2 HOLES
1 1/4
3/4
1/2 DRILL
2 HOLES
IN LINE
1
3/4
1
1 3/8 R
45°
1/2
3/8
1/2
4 1/2
3/8
3 1/2
2 1/4
1 9/16
5/8
1 13/16
2 1/4
F.A.O.
BRASS
2 REQ'D.
Rod Support

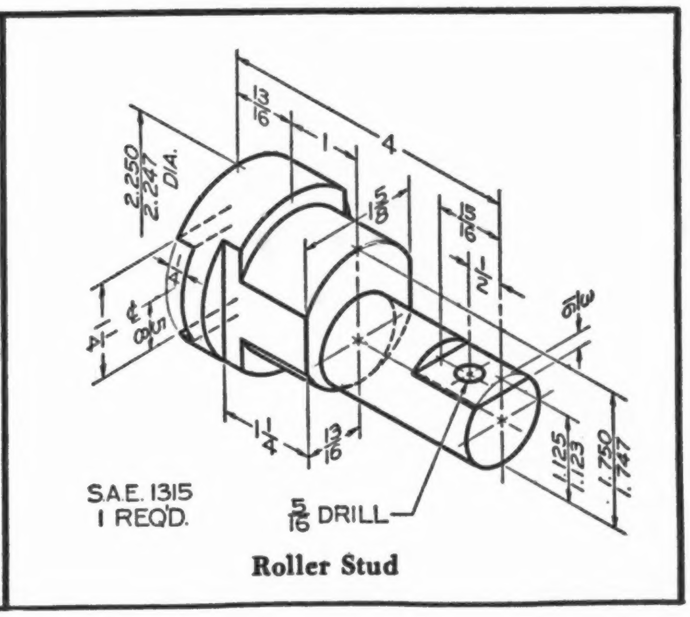
Problem 5.


7/16
7/16
1 1/2
1/2
7/16
3/4 R
1/2
7/16
9/16
3/4
4 5/8
5
3/4
9/16
1 1/8
2 1/4
C. I.
1 REQ'D.
Tailstock Clamp

Problem 6.


.625
.623
.500
.502 REAM
1045 STEEL
PLATE
"f" ALL OVER
2 REQD
9/16 R
2 5/8 R
1 1/2
5/16
3/8
3/4 R
15°
1 11/16
.500
.502
1 3/8
11/16
13/16 R
.750
.751 REAM
7/8
.531
.521
2 1/4
1.125
1.123
GRIND
Toggle Lever

Problem 7.


13/16
1
4
2.250
2.247 DIA.
1 5/8
1 5/16
1 1/2
1/4
5/16
3/16
1 1/4
13/16
1.125
1.123
1.750
1.747
S.A.E. 1315
1 REQ'D.
5/16 DRILL
Roller Stud

Problem 8.

Introduction to Shop Processes

Lesson 2

OBJECTIVES:

1. To emphasize the importance of the draftsman becoming familiar with shop processes.
2. To relate, in an introductory manner, shop processes to information which should be found on drawings.
3. To encourage the use of reference materials.

REFERENCES:

1. Chapter 10, TECHNICAL DRAWING, Giesecke, Mitchell, and Spencer.
2. Chapter 7, ENGINEERING DRAWING, Zozzora.
3. Units 57-92, GENERAL SHOP, Gronemm and Feirer, 3rd Edition, McGraw-Hill, N. Y.
4. MACHINE SHOP: OPERATIONS AND SET-UPS, Porter, Lawshe, Lascoe, 6th Edition, American Technical Society, Chicago, Ill.
5. FORGING AND WELDING, Smith, McKnight, and McKnight, Bloomington, Ill.

INFORMATION:

A draftsman must be familiar with materials, methods of construction, and shop requirements if he is to be at all successful. You should lay hold of every possible opportunity to familiarize yourself with fundamental shop processes, especially PATTERN MAKING, FOUNDRY, FORGING, and MACHINE SHOP PRACTICE.

All manufacturing operations begin with raw materials which must be changed by one or more of several operations before the finished product is realized. These operations include:

1. removing part of the original material.
2. adding material.
3. redistributing original material.
4. changing properties of materials.

The draftsman should be familiar with the various methods of changing materials into the finished products so that he can intelligently call for these operations on his drawings.

This lesson provides only a limited introduction to shop processes. Many texts are written on shop processes alone, and reference work is absolutely necessary.

Before a detailed drawing of any part can be prepared, the processes which are to be used in manufacturing have to be determined. These decide the choice and types of views, choice of dimensions, and the tolerances and notes which must be included.

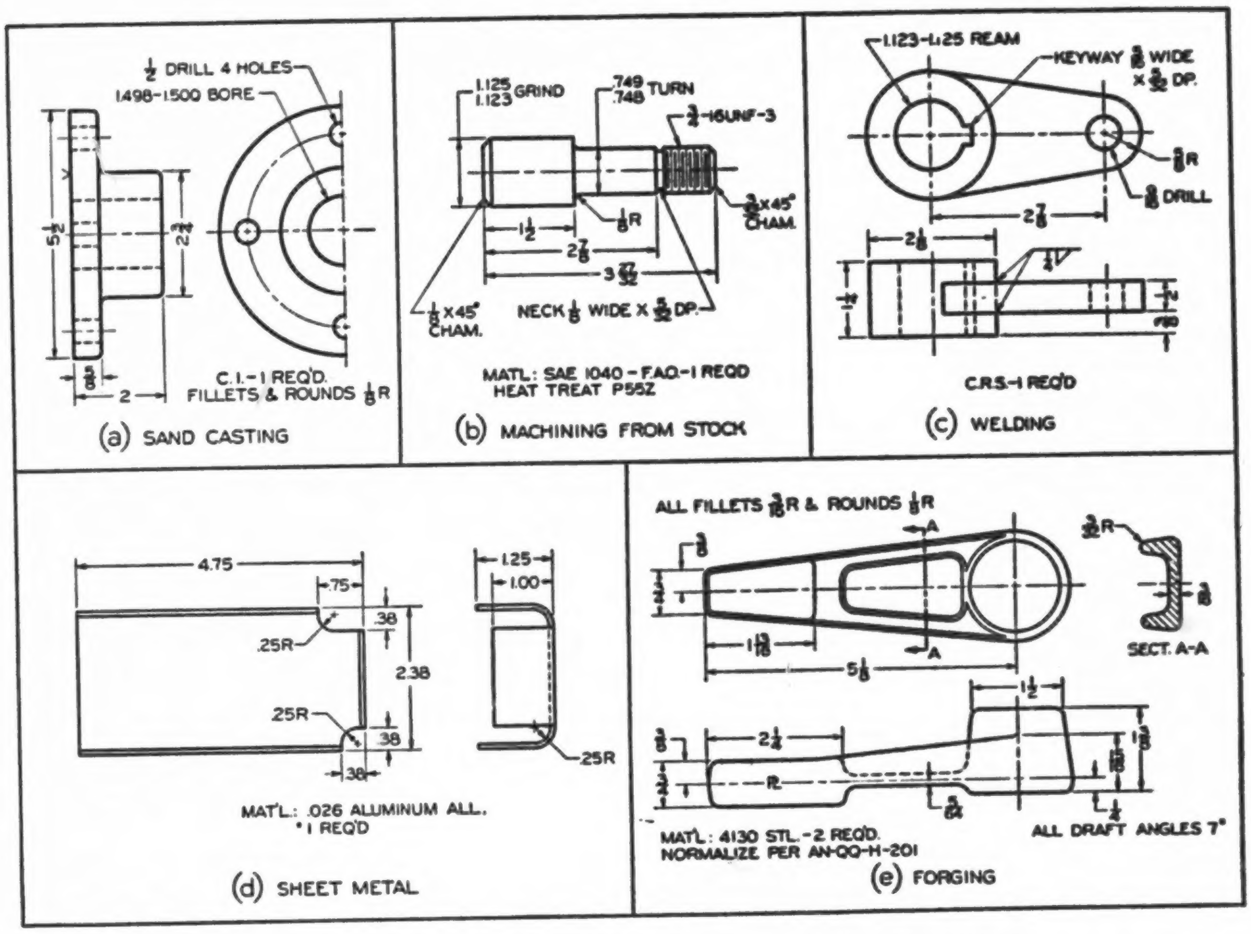
Outline of Processes

The following is a listing of a few of the possible shop operations which may be called for under each of the categories mentioned above.

1. REMOVING MATERIAL
    - drilling
    - boring and counter boring
    - reaming
    - counter sinking
    - turning and cutting
    - shaping
    - milling
    - grinding
    - planing
    - broaching
    - punching
    - threading and topping
2. ADDING MATERIAL
    - welding
    - brazing
    - soldering
    - spraying
    - electro-chemical plating
    - laminating
3. REDISTRIBUTING MATERIAL
    - casting
    - pressing and forming
    - drawing
    - knurling
    - extruding
    - spinning
    - forging
4. CHANGING PROPERTIES OF MATERIALS
    - annealing
    - alloying
    - tempering
    - heat treating
    - surface hardening
    - induction and flame hardening

With each passing day additional procedures are being developed to produce parts and products in an improved and efficient manner. Your drawings will reflect your knowledge as you learn applications of the various processes.

There are many terms related to manufacturing operations which are often used on machine drawings. In addition, there are many machines which may be used to accomplish the processes called for on drawings. In the following pages mention will be made of just a few basic machines and related terms and processes.


½ DRILL 4 HOLES
1.498-1.500 BORE
5½
2¾
⅝
2
C.I.-1 REQ'D.
FILLETS & ROUNDS ⅛R
1.125 1.123 GRIND
.749 .748 TURN
¾-16UNF-3
⅛R
1½
2⅞
3 27/32
1/16 X45° CHAM.
1/16 X45° CHAM.
NECK ⅛ WIDE X 5/32 DP.
MATL: SAE 1040 - F.A.O.-1 REQD
HEAT TREAT P55Z
1.123-1.125 REAM
KEYWAY 3/16 WIDE X 3/32 DP.
⅜R
⅜ DRILL
2⅞
2⅛
¼
C.R.S.-1 REQ'D
4.75
.75
.38
.25R
2.38
.25R
.38
.38
1.25
1.00
.25R
MAT'L: .026 ALUMINUM ALL.
1 REQ'D
ALL FILLETS 3/16R & ROUNDS ⅛R
A
A
3/32R
SECT. A-A
1 13/16
5⅛
1½
2¼
R
1⅜
5/64
¼
MAT'L: 4130 STL.-2 REQ'D.
NORMALIZE PER AN-QQ-H-201
ALL DRAFT ANGLES 7°

(a) SAND CASTING (b) MACHINING FROM STOCK (c) WELDING

(d) SHEET METAL (e) FORGING

Drawings for Different Manufacturing Processes.

Figure 1.

Casting

The casting of metals can be accomplished by any of several means. Sand casting, however, is by far the most extensively used method. Figure 2 illustrates some of the terms connected with the process.

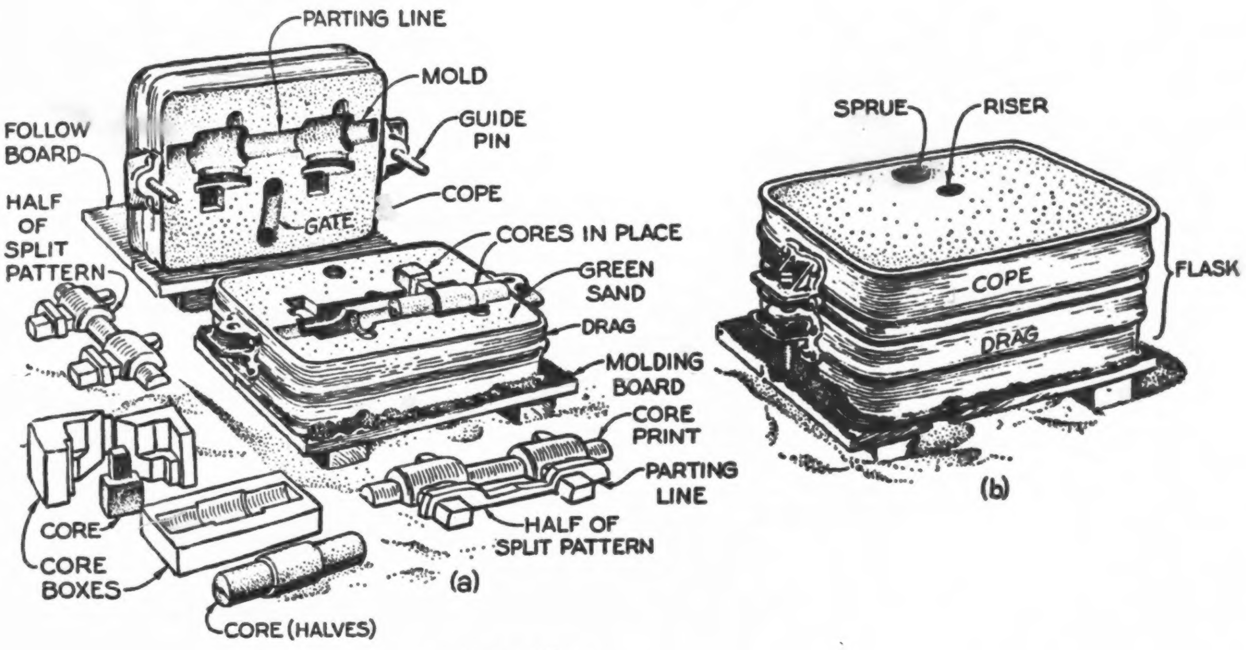
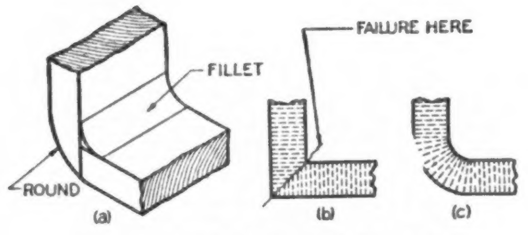

PARTING LINE
MOLD
FOLLOW BOARD
GUIDE PIN
HALF OF SPLIT PATTERN
COPE
GATE
CORES IN PLACE
GREEN SAND
DRAG
MOLDING BOARD
CORE PRINT
PARTING LINE
CORE
CORE BOXES
HALF OF SPLIT PATTERN
CORE (HALVES)
(a)
SPRUE
RISER
FLASK
COPE
DRAG
(b)

Figure 2.

Sand Molding

A pattern must be made of wood or other material to form an impression of the desired shape in the sand. The pattern is then removed. Internal hollow forms or depressions, such as holes, are formed by means of sand "cores" placed or suspended within the mold. As the molten metal is poured into the mold it assumes the form of each depression, forming a part duplicating the original pattern.



Fillets and Rounds.

Figure 3.

One pair of terms used extensively in connection with castings is "Fillets and Rounds" (figure 3). Fillets provide strength in the corners of castings to prevent possible weak points leading to failures. The strength of castings is almost doubled by the use of fillets.

Rounds are formed to overcome sharp corners and to prevent chipping of the castings and to ease the removal of parts from the mold. Figure 3b-c shows how the crystals of cast metal arrange themselves to provide internal strength of castings.

Castings also may include a "draft" angle of 2°-7° providing a taper which permits the withdrawal of the part from the mold.

Forging

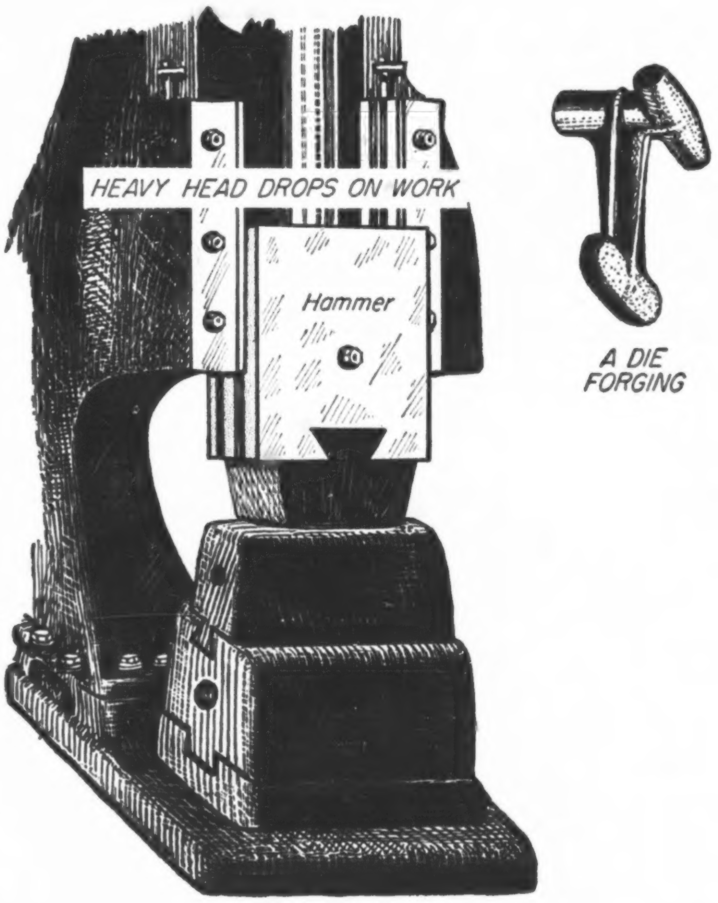
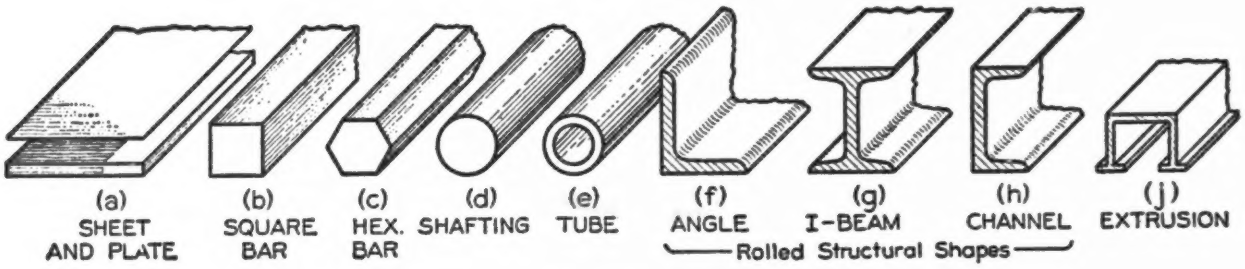

HEAVY HEAD DROPS ON WORK
Hammer
A DIE FORGING

Figure 4.

Forging press.

The terms "fillets and rounds" and "draft angle" also apply to forging operations. In this case, the mold is located in a hammering or pressing machine used to change the shape of the metals. Here again, the internal arrangement of the molecules occurs, leading to the strengthening of the material. Forging also, to some extent, compresses the steel to provide even greater strength.

Stock Forms of Materials



Common Stock Forms.

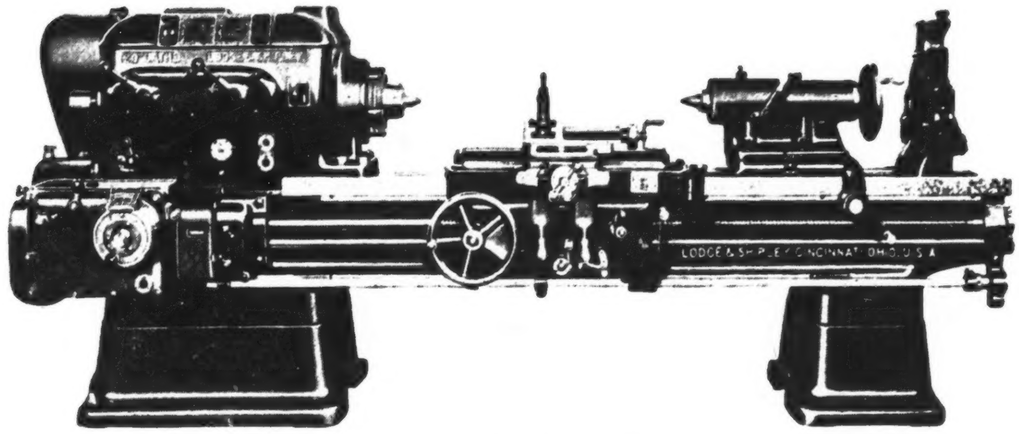
Figure 5.

In many design applications, time and expense can be saved by the use of stock forms of many materials. Steel, brass, copper, aluminum, and other materials are manufactured in many commonly required forms. The draftsman should become familiar with catalogs secured from manufacturers of these products to avail himself of a working knowledge of available stock materials. Various chemical alloys, hardnesses, and finish qualities are provided by most of the metal manufacturers in their products. Among the hundreds of manufacturers are:

United States Steel
Bethlehem Steel
Alcoa Aluminum
Reynolds Aluminum
Revere Copper and Brass
American Pipe and Tube

Machine Tools

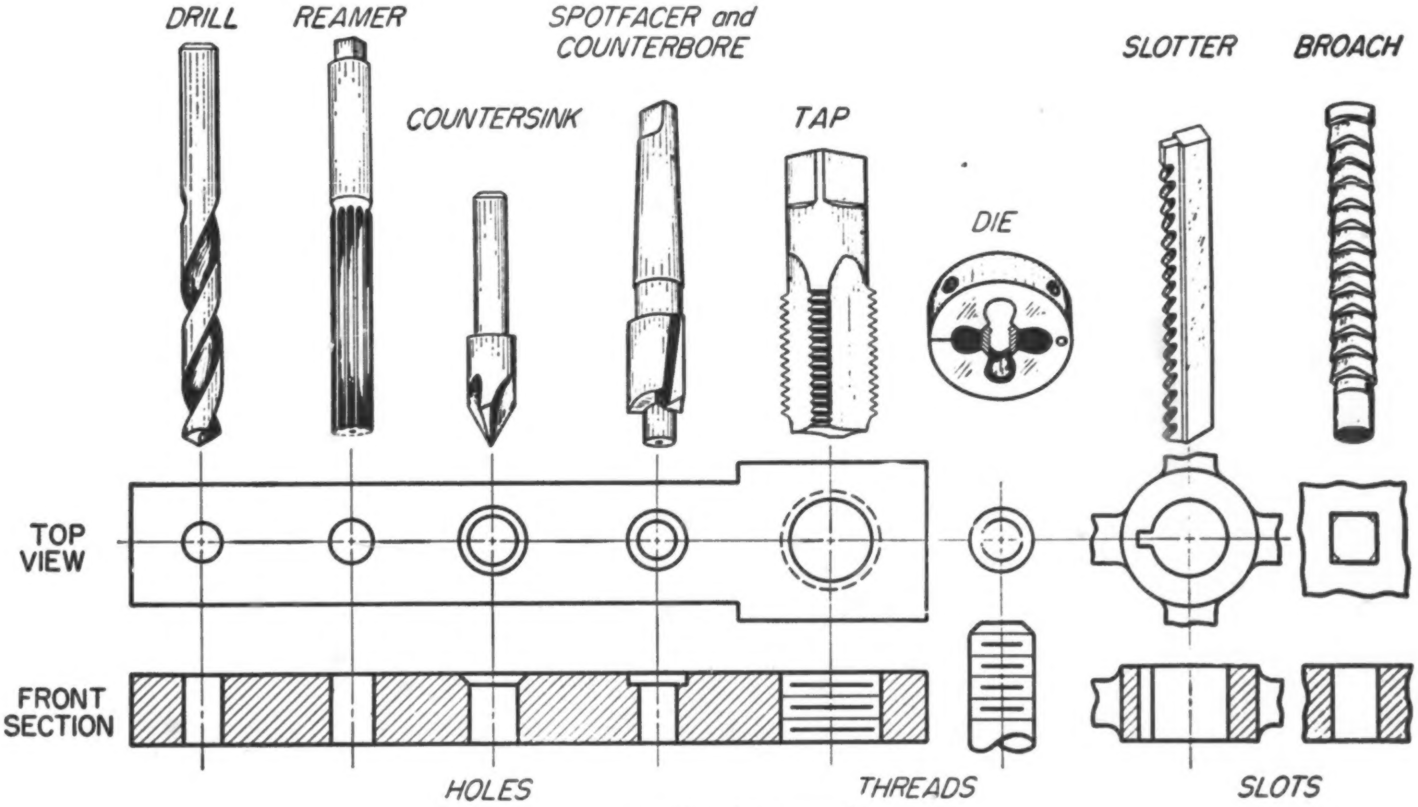
Some of the more common MACHINE TOOLS used to execute the many processes required in manufacturing operations are the ENGINE LATHE, DRILL PRESS, MILLING MACHINE, SHAPER, GRINDING MACHINE, PLANER, and BORING MILL. These machines and some related processes are illustrated in figures 6 through 18.


LODGE & SHIPLEY CINCINNATI OHIO U.S.A.

Engine Lathe.

Figure 6.

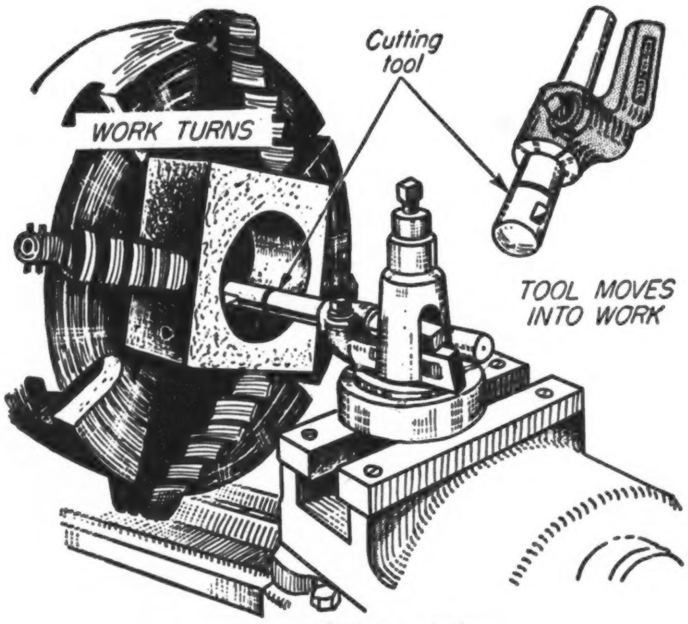
The tools which are used with the mentioned machines are possibly the most important pieces of equipment in the machine shop. Without tooling, the machines which merely provide specialized applications of power would be worthless.


DRILL
REAMER
COUNTERSINK
SPOTFACER and COUNTERBORE
TAP
DIE
SLOTTER
BROACH
TOP VIEW
FRONT SECTION
HOLES
THREADS
SLOTS

Machine-shop operations.

Figure 7.

Some tool forms are illustrated in figure 7. Connections between the drawing representations of these processes and the tools used to perform them can be gained from the illustration.



Boring on a lathe.

Figure 8.

Throughout your drawing experience you will be applying references to machine operations to an ever increasing extent. With increased knowledge you will also learn improved drafting techniques which will enable you to produce practical and worthy machine drawings.

Do's and Don'ts of Practical Design

In figures 9 and 10 are shown a number of examples in which a knowledge of shop processes and limitations is essential for good design.

Many difficulties in producing good castings result from abrupt changes in section or thickness. In figure 9a, rib thicknesses are uniform so that the metal will flow easily to all parts. Fillet radii are equal to the rib thickness--a good general rule to follow. When it is necessary to join a thin member to a thicker member, the thin member should be thickened as it approaches the intersection, as shown at 9(b).

At (c), (g), and (h), coring is used to produce walls of more uniform sections. At (d) an abrupt change in sections is avoided by making thinner walls and leaving a collar, as shown.

At (e) and (f) are shown examples in which the preferred design will tend to allow the castings to cool without introducing internal stresses. The less desirable design is more likely to crack as it cools, since there is no "give" in the design. Curved spokes are preferable to straight spokes, and an odd number of spokes is better than an even number because direct stresses along opposite spokes are avoided.

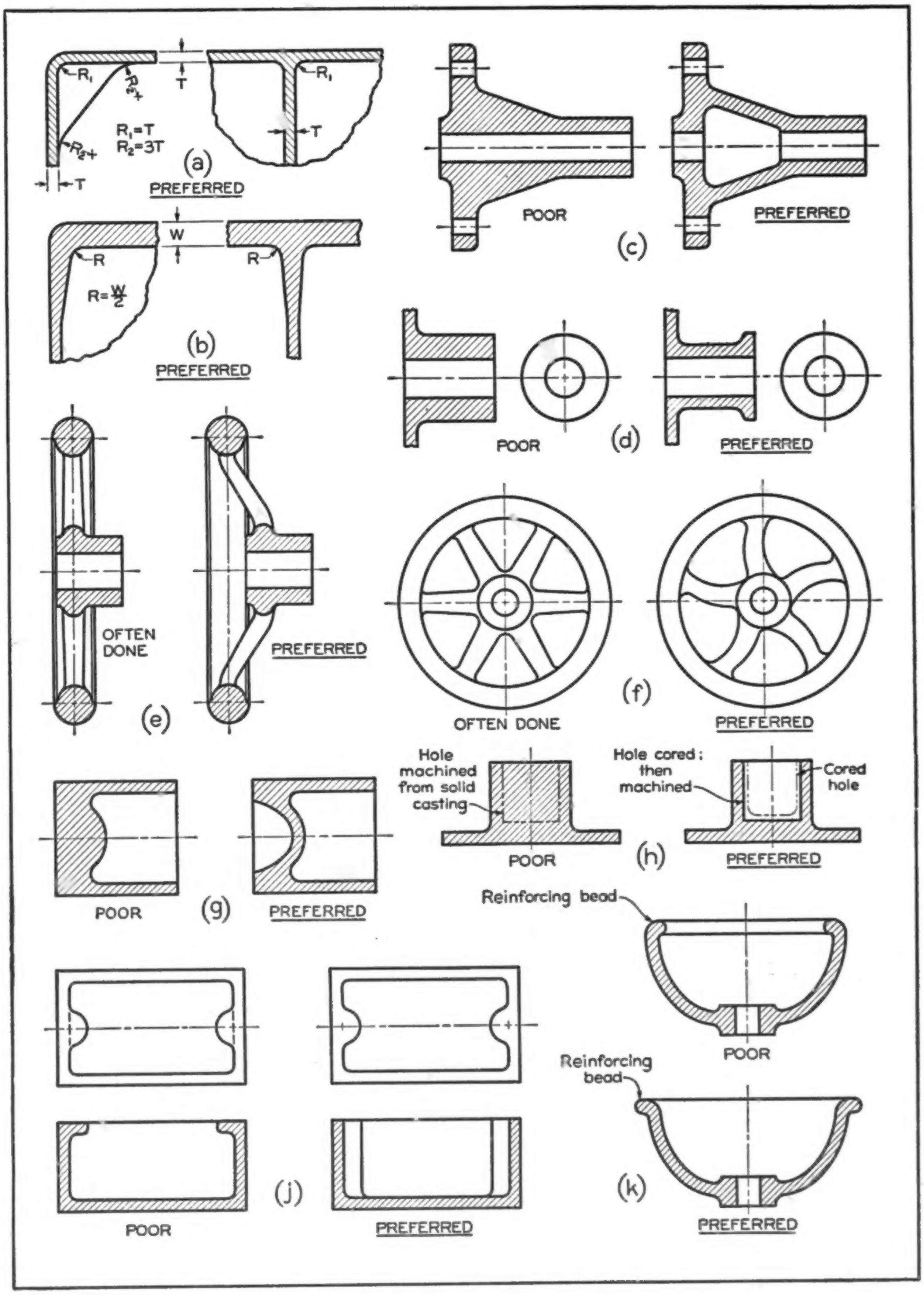

R1
R2+
R1=T
R2=3T
T
(a)
PREFERRED
W
R
R=W/2
(b)
PREFERRED
POOR
PREFERRED
(c)
POOR
(d)
PREFERRED
OFTEN DONE
PREFERRED
(e)
(f)
OFTEN DONE
PREFERRED
Hole machined from solid casting
Hole cored; then machined
Cored hole
POOR
(h)
PREFERRED
POOR
(g)
PREFERRED
Reinforcing bead
POOR
Reinforcing bead
(k)
PREFERRED
POOR
(j)
PREFERRED

Figure 9. **Casting Design Do's and Don'ts.**

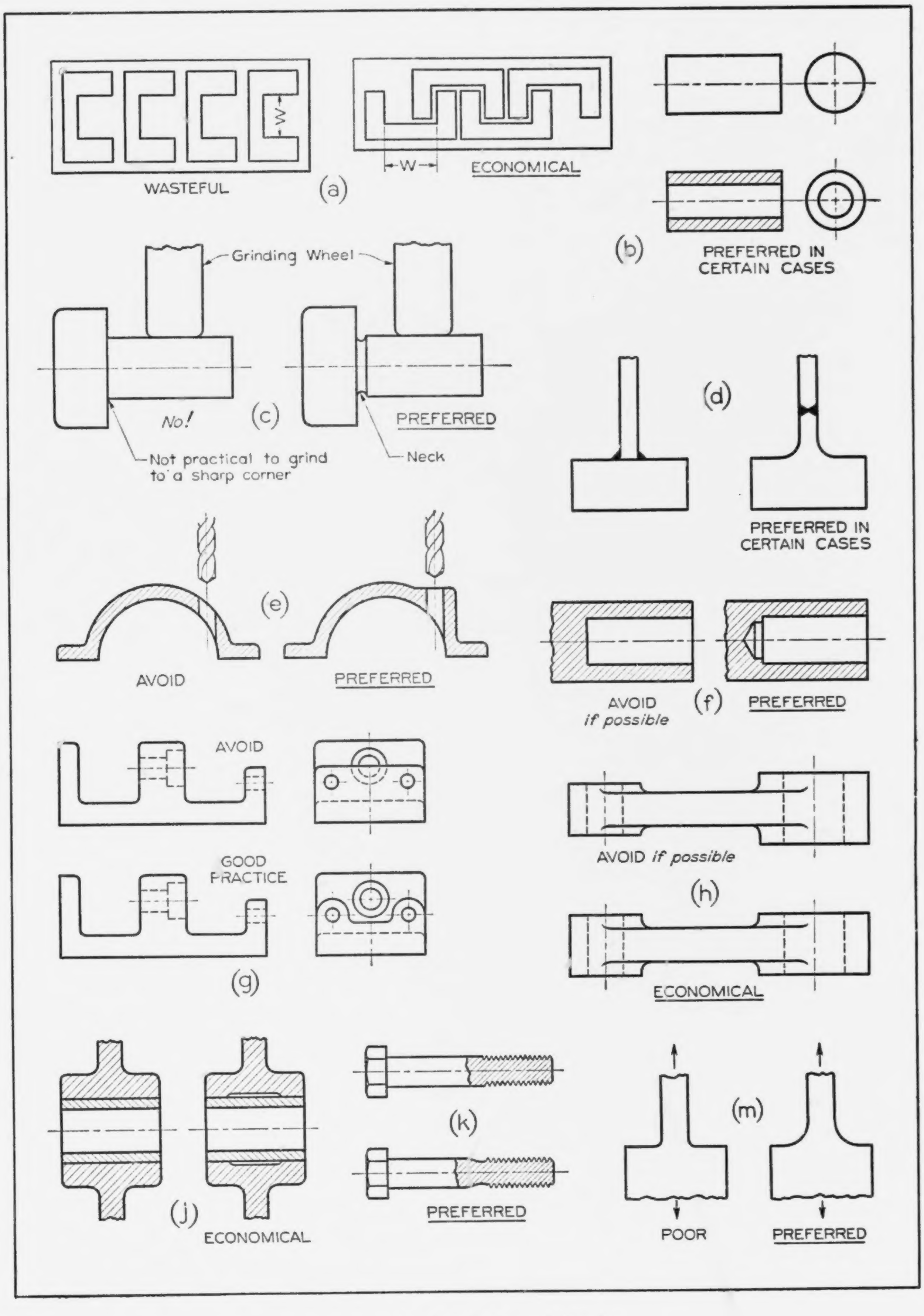
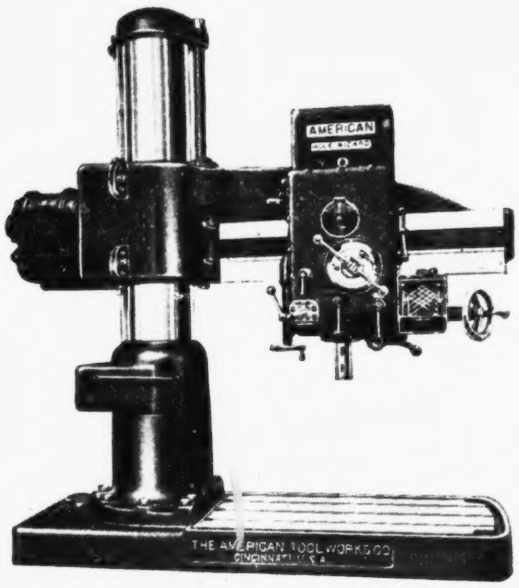

W
WASTEFUL
(a)
W
ECONOMICAL
(b)
PREFERRED IN CERTAIN CASES
Grinding Wheel
No!
(c)
Not practical to grind to a sharp corner
PREFERRED
Neck
(d)
PREFERRED IN CERTAIN CASES
(e)
AVOID
PREFERRED
AVOID if possible
(f)
PREFERRED
AVOID
GOOD PRACTICE
(g)
AVOID if possible
(h)
ECONOMICAL
(j)
ECONOMICAL
(k)
PREFERRED
(m)
POOR
PREFERRED

Figure 10. **Design Do's and Don'ts.**

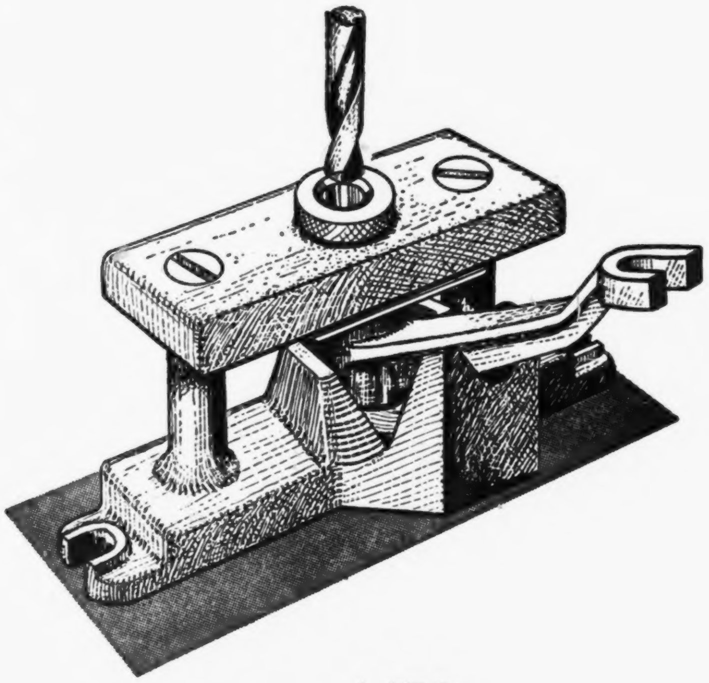
3



Courtesy American Tool Works

Radial Drill Press.

Figure 11.

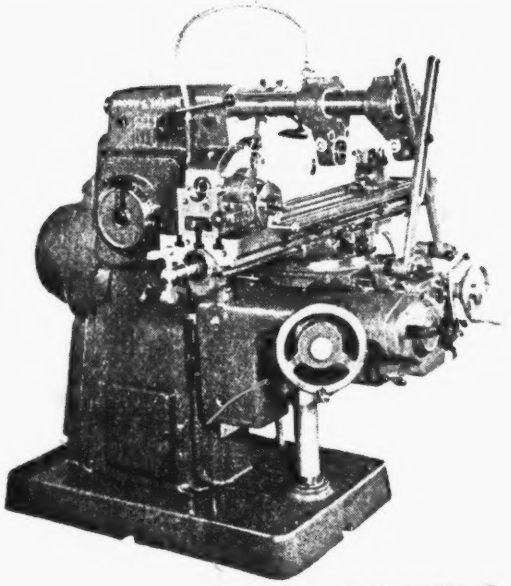


A drill jig.

Figure 12.

The design of a part may cause unnecessary trouble and expense for the pattern shop and foundry without any gain in the usefulness of the design. For example, in the "poor" designs at figure 9j-k, one-piece patterns would not withdraw from the sand, and two-piece patterns would be necessary. In the "preferred" examples, the design is just as useful and is conducive to economical work in the pattern shop and foundry.

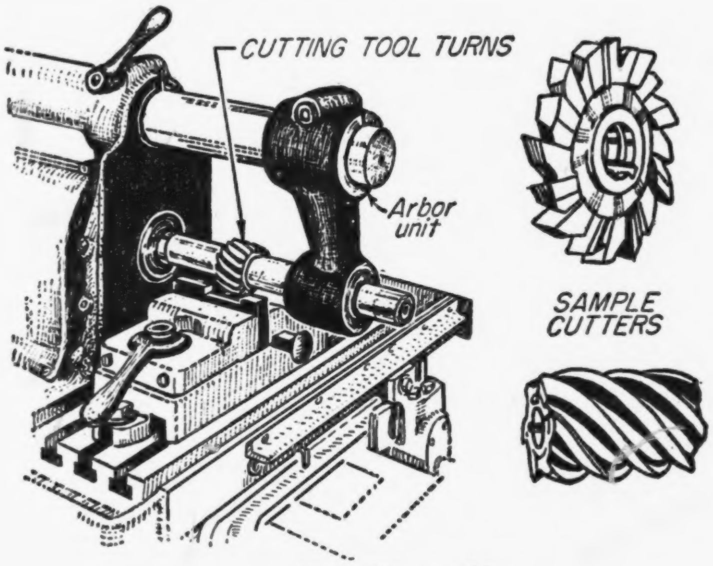
As shown in figure 10a, a narrower piece of stock sheet metal can be used for certain designs that can be linked or overlapped. In this case, the stampings may be overlapped if dimension W is increased slightly as shown. By such an arrangement, great savings in scrap metal can often be effected.



Courtesy Brown & Sharpe Mfg. Co.

Milling Machine.

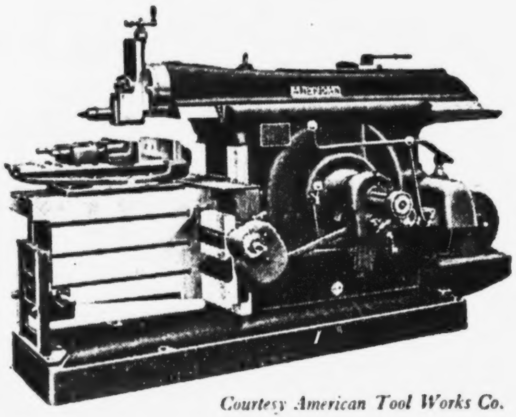
Figure 13.



The milling machine.

Figure 14.

The maximum hardness that can be obtained in the heat treatment of steel depends on the carbon content of the steel. To get this hardness, it is necessary to cool rapidly (quench) after heating to the temperature required. In practice, it is often impossible to quench uniformly because of the design. In figure 10b the piece is solid and will harden well on the outside but will remain soft and relatively weak on the inside. However, as shown in the preferred example, a hollow piece can be quenched from both the outside and the inside. Thus it is possible for a hardened hollow shaft to be stronger than a hardened solid shaft of the same diameter.



Courtesy American Tool Works Co.

Shaper.

Figure 15.

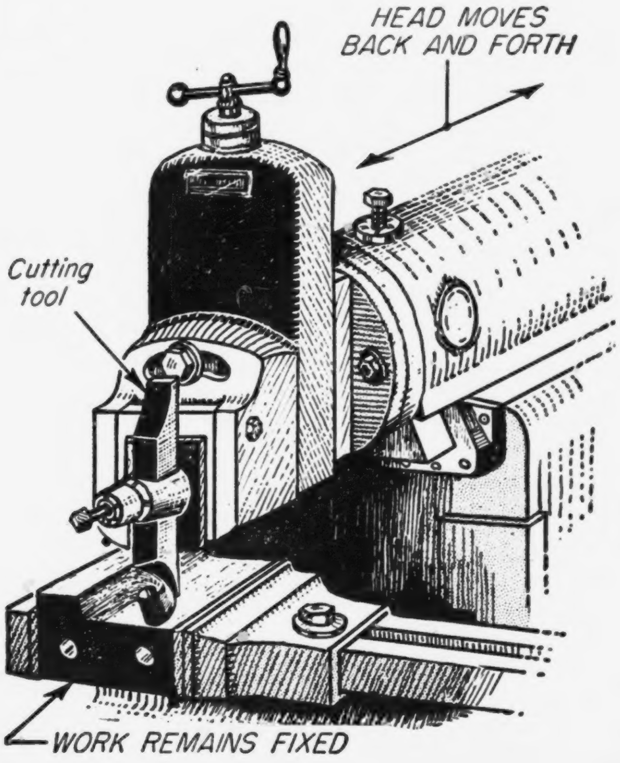


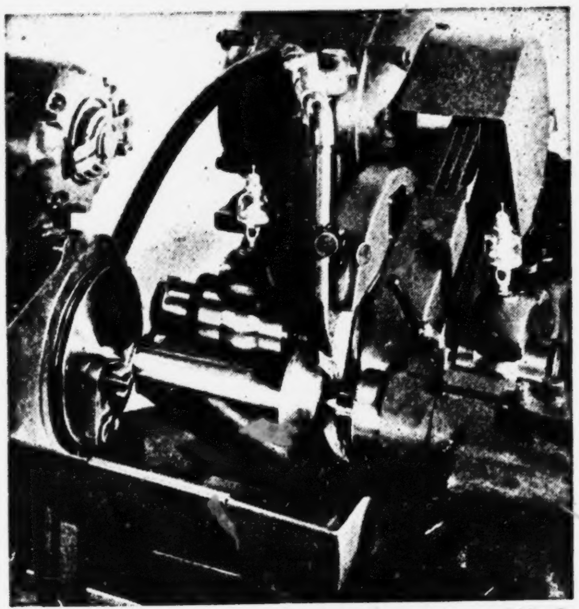
Figure 16.

As shown in figure 10c, the addition of a rounded groove, called a "neck", around a shaft next to a shoulder will eliminate a practical difficulty in precision grinding. It is not only more expensive to grind a sharp internal corner, but such sharp corners often lead to cracking and failure.

The design at the right in figure 10d eliminates a costly "reinforced" weld which would be required by the design on the left. The strong virgin metal with a generous radius is present at the point at which the stress is likely to be most severe. It is possible to make the design on the left as strong as the design on the right, but it is more expensive and requires expert skill and special equipment.

It is difficult to drill into a slanting surface as shown at the left in figure 10e. The drilling will be greatly facilitated if a boss is provided as shown at the right.

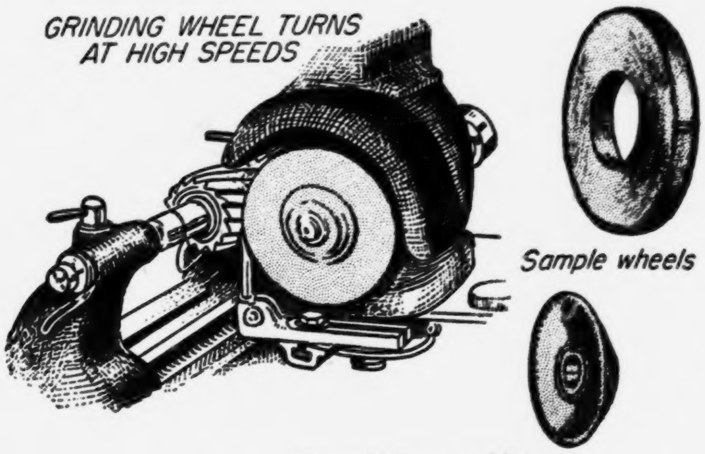
In figure 10f the design at the left requires accurately boring or reaming a blind hole all the way to a flat bottom, which is difficult and expensive. It is better to drill deeper than the hole is to be finished,as shown at the right,in order to provide room for tool clearance and for chips.



Courtesy Brown & Sharpe Mfg. Co.

Grinding Machine.

Figure 17.


GRINDING WHEEL TURNS AT HIGH SPEEDS
Sample wheels

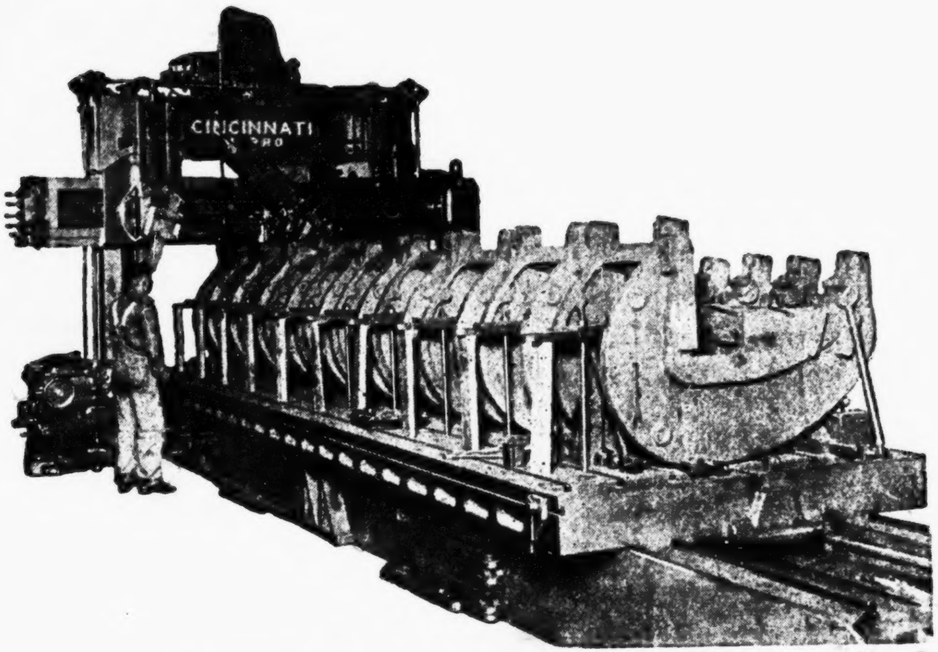
The grinding machine.

Figure 18.

In the upper example of figure 10g, the drill and counterbore cannot be used for the hole in the center piece because of the raised portion at the right end. In the approved example, the end is redesigned to provide access for the drill and counterbore.

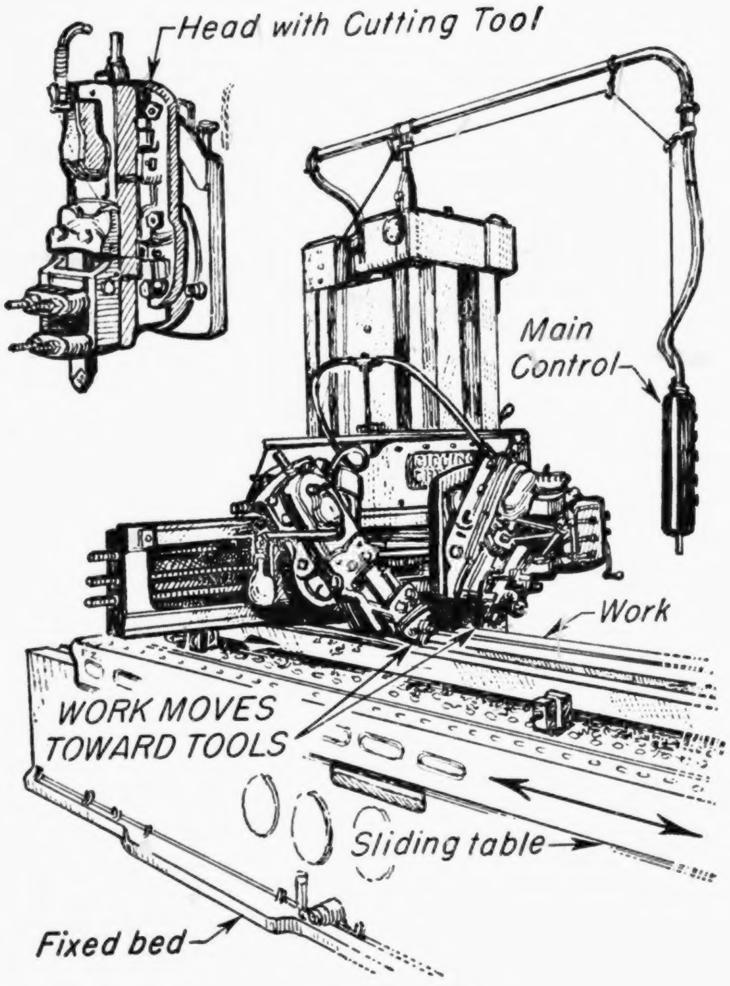
In the top design of figure 10h, the ends are not the same height. As a result, each flat surface must be machined separately. In the bottom design the ends are the same height, the surfaces are in line horizontally, and only two machining operations are necessary. It is always good design to simplify and limit the machining as much as possible.

The design at the left in figure 10j requires that the housing be bored for the entire length in order to receive a pressed bushing. Machining time can be decreased if the cored recess is made as shown. This assumes that average loads would be applied in use.


CINCINNATI

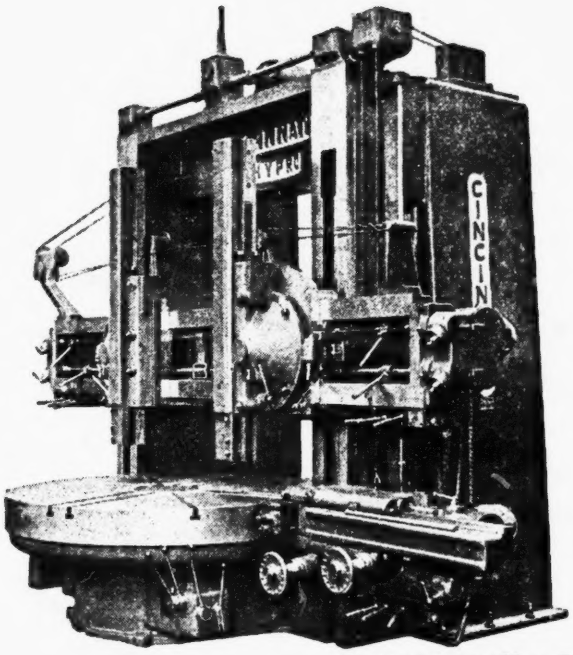
Courtesy Cincinnati Planer Co.

Figure 19. **Planer.**


Head with Cutting Tool
Main Control
Work
WORK MOVES TOWARD TOOLS
Sliding table
Fixed bed

The planer.

Figure 20.



Courtesy Cincinnati Planer Co.

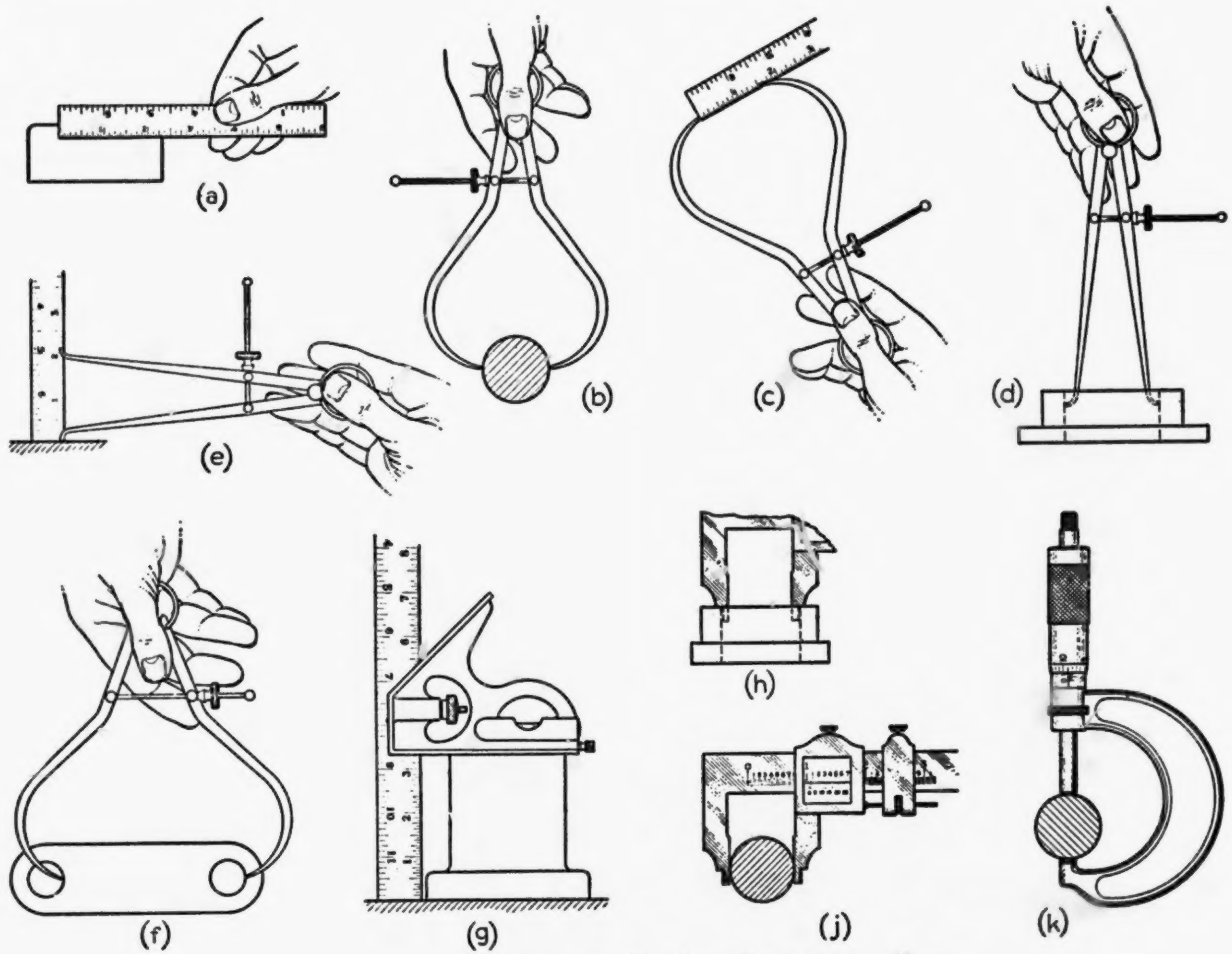
Vertical Boring Mill.

Figure 21

In figure 10k the lower bolt is encircled by a rounded groove no deeper than the root of the thread. This makes a gentle transition from the small diameter at the root of the threads and the large diameter of the body of the bolt, producing less stress concentration and a stronger bolt. In general, sharp internal corners should be avoided as points of stress concentration and possible failure.

In figure 10m a quarter-inch steel plate is shown being pulled. By increasing the radius from $\frac{1}{8}$R to $\frac{1}{2}$R, the strength of the plate is increased a great deal by decreasing stress concentration.

Measuring Devices



Measuring Devices Used in the Shop.

Figure 22.

The machinist uses various measuring devices to correctly gauge his work against drawing requirements. The engineering draftsman should at least have a working knowledge of some of the measuring instruments used by the machinist in order to intelligently specify the degree of accuracy desired in work produced from his designs.

The MACHINIST'S STEEL RULE or SCALE is the most commonly used measuring tool in the shop. The smallest divisions on one scale of this rule are $\frac{1}{64}$", and such a scale is used for common fractional dimensions. Also, many machinists' rules have a decimal scale with the smallest division of 0.01" which is used for dimensions given on the drawing by the decimal system. For checking the nominal size of outside diameters, the OUTSIDE SPRING CALIPER is used as shown at figure 22d-e. Another use for the outside caliper (f) is to check the nominal distance between holes (center to center). The COMBINATION SQUARE may be used for checking height as shown at (g) and for a variety of other measurements.

For dimensions that require more precise measurements, the VERNIER CALIPER (h and j) or the MICROMETER CALIPER (k) may be used. It is common practice to check measurements to 0.001" with these instruments, and in some instances they are used to measure directly to 0.0001".

Most measuring devices in the shop are adjustable so they can each be employed to measure any size within their range of designed usage. There is also a need for measuring devices designed to be used for only one particular dimension. These are called FIXED GAGES because their setting is fixed and cannot be changed.

The subject of gages and gaging is a specialized field and involves so many technical considerations that large companies employ highly trained men to attend to nothing but this one feature of their operations.

Since there are literally hundreds of terms related to machine shop work today, the draftsman should build a useful library of reference materials related to his particular subject requirements.

The glossary following this lesson provides definitions of some common forms and terms applied quite often in the production of machine drawings.

ASSIGNMENT:

1. List some reference books available to you on the subject of machine shop operations.

2. Where, or in what books, can you find information on parts and manufacturing specifications?

3. In your own words, why is it important to you as a student draftsman to know something about shop operations?

4. List three common household appliances of different materials and manufacture. Using the list of methods for changing raw material forms provided at the beginning of this lesson, discuss how each relates in terms of shop processes to the manufacture of each appliance.

5. List two parts of an automobile made by using each of the following machines or processes:

casting	machine lathe
forging	milling machine
pressing and forming	drill press

GLOSSARY OF COMMON SHOP TERMS

(n) means a (noun)
(v) means a (verb)

ADDENDUM (n): Radial distance from pitch circle to top of gear tooth.

ALLEN SCREW (n): Special set screw or cap screw with hexagon socket in head.

ALLOWANCE (n): Minimum clearance between mating parts.

ALLOY (n): Two or more metals in combination.

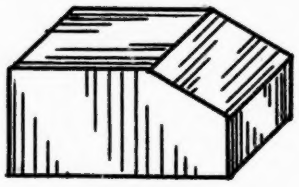
ALUMINUM (n): A lightweight but strong metal. Often alloyed with copper to increase hardness and strength.

ANGLE IRON (n): A structural shape whose section is a right angle.

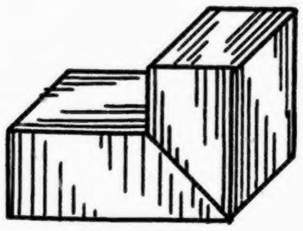
ANNEAL (v): To heat and cool gradually to increase ductility.

ARC WELD (v): To weld by electric arc.

BABBIT (n): A soft alloy used for bearings; mostly tin with small amounts of copper and antimony.



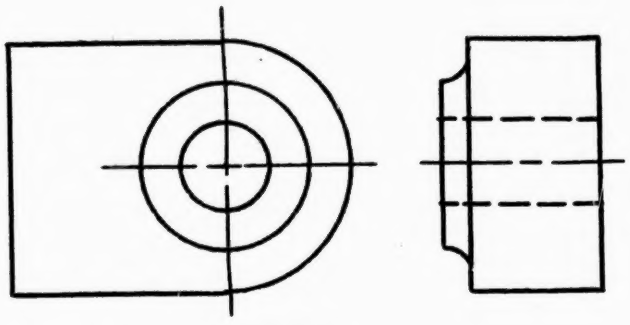
BEVEL



MITER

BEVEL (n): An inclined edge, not at right angle to adjoining edge. At 45°, a miter is formed.

BORE (v): To enlarge a hole with a boring bar or tool in a lathe, drill press, or boring mill.



BOSS

BOSS (n): A cylindrical projection on a casting or forging.

BRASS (n): An alloy of copper and zinc.

BRAZE (v): To join metals with hard solder of brass or zinc.

BRINELL (n): A method of testing hardness of metal.

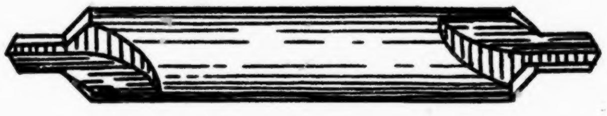
BROACH (n): A long cutting tool with a series of teeth that gradually increase in size which is forced through a hole or over a surface to produce a desired shape.

BRONZE (n): An alloy of eight or nine parts of copper and one part of tin.

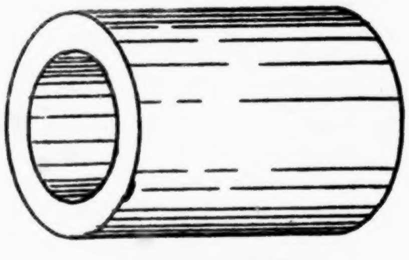
BUFF (v): To finish or polish on a buffing wheel composed of fabric using abrasive powders.

BURNISH (v): To finish or polish by pressure upon a smooth rolling or sliding tool.

BURR (n): A jagged edge on metal left by cutting tools.



CENTER DRILL



BUSHING

BUSHING (n): A replaceable lining or sleeve for a bearing.

CALIPERS (n): Instruments (of several types) for measuring diameters.

CAM (n): A rotating member for changing circular motion to reciprocating motion.

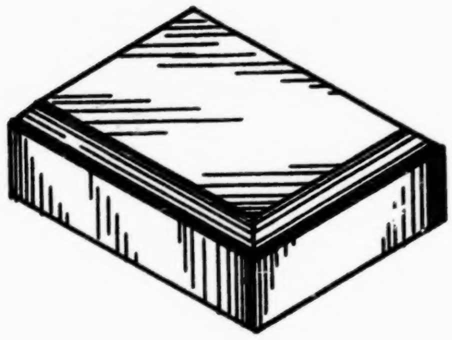
CARBURIZE (v): To heat a low-carbon steel to approximately 2000°F. in contact with material which adds carbon to the surface of the steel, and to cool slowly in preparation for heat treatment.

CASEHARDEN (v): To harden the outer surface of a carburized steel by heating and then quenching.

CASTING (n): A metal object produced by pouring molten metal into a mold.

CAST IRON (n): Iron melted and poured into molds.

CENTER DRILL (n): A special drill to produce bearing holes in the ends of a workpiece to be mounted between centers. Also called a "combined drill and countersink."



CHAMFER

CHAMFER (n): A narrow inclined surface along the intersection of two surfaces.

CHASE (v): To cut threads with an external cutting tool.

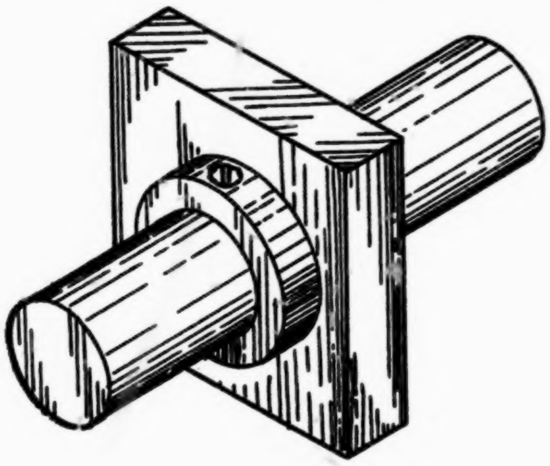
CHILL (v): To harden the outer surface of cast iron by quick cooling, as in a metal mold.

CHIP (v): To cut away metal with a cold chisel.

CHUCK (n): A mechanism for holding a rotating tool or workpiece.

COIN (v): To form a part in one stamping operation.

COLD ROLLED STEEL (n): Open hearth or Bessemer steel containing 0.12% to 0.20% carbon which has been rolled while cold to produce a smooth, accurate stock.



COLLAR

COLLAR (n): A round flange or ring fitted on a shaft to prevent sliding.

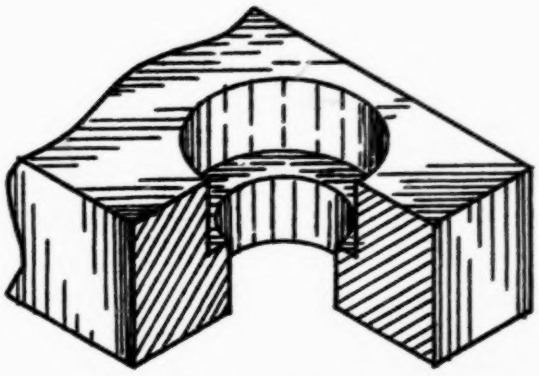
COLORHARDEN (v): Same as case-harden except that it is done to a shallower depth, usually for appearance only.

COPE (n): The upper portion of a flask used in molding.

CORE (v): To form a hollow portion in a casting by using a dry-sand core or a green-sand core in a mold.

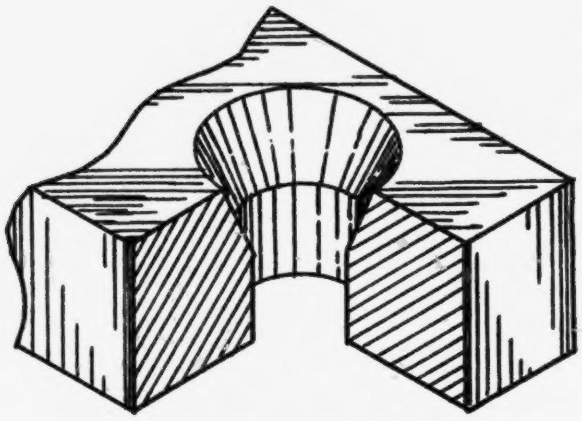
COREPRINT (n): A projection on a pattern which forms an opening in the sand to hold the end of a core.

COTTER PIN (n): A split pin used as a fastener, usually to prevent a nut from unscrewing.



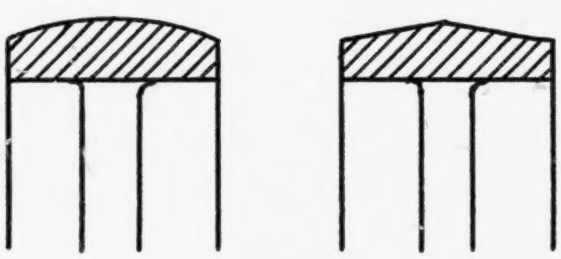
COUNTERBORE

COUNTERBORE (v): To enlarge an end of a hole cylindrically with a counterbore.



COUNTERSINK

COUNTERSINK (v): To enlarge an end of a hole conically, usually with a countersink.



CROWN

CROWN (n): A raised contour, as on the surface of a pulley.

CYANIDE (v): To surface harden steel by heating in contact with a cyanide salt,followed by quenching.

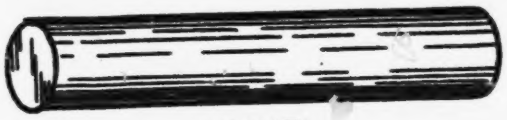
DEVELOPMENT (n): Drawing of the surface of an object unfolded or rolled out on a plane.

DIE (n): 1) Hardened metal piece shaped to cut or form a required shape in a sheet of metal by pressing it against a mating die. 2) Also used for cutting small threads; in a sense is opposite to a tap.

DIE CASTING (n): Process of forcing molten metal under pressure into metal dies or molds, producing a very accurate and smooth casting.

DIE STAMPING (n): Process of cutting or forming a piece of sheet metal with a die.

DOG (n): A small auxiliary clamp for preventing work from rotating in relation to the faceplate of a lathe.



DOWEL

DOWEL (n): A cylindrical pin commonly used to prevent sliding between two contacting flat surfaces.

DRAFT (n): The tapered shape of the parts of a pattern to permit it to be easily withdrawn from the sand or, on a forging, to permit it to be easily withdrawn from the dies.

DRAG (n): Lower portion of a flask used in molding.

DRAW (v): To stretch or otherwise deform metal. Also to temper steel.

DRILL (v): To cut a cylindrical hole with a drill.

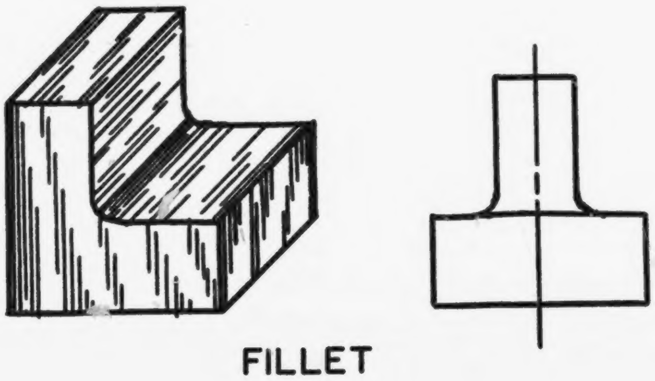
DRILL PRESS (n): A machine for drilling and other hole-forming operations.

DROP FORGE (v): To form a piece while hot between dies in a drop hammer or with great pressure.

FACE (v): To finish a surface at right angles, or nearly so, to the center line of rotation on a lathe.

FEATHER KEY (n): A flat key which is partly sunk in a shaft and partly in a hub, permitting the hub to slide lengthwise of the shaft.

FILE (v): To finish or smooth with a file.



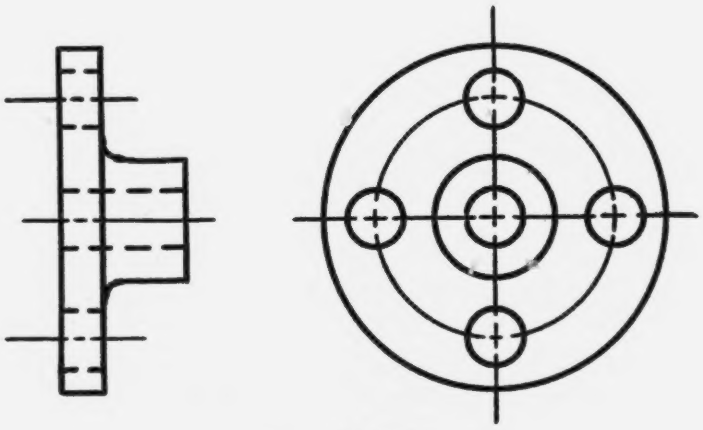
FILLET

FILLET (n): An interior rounded intersection between two surfaces.

FIN (n): A thin extrusion of metal at the intersection of dies or sand molds.

FIT (n): Degree of tightness or looseness between two mating parts.

FIXTURE (n): A special device for holding the work in a machine tool.



FLANGE

FLANGE (n): A relatively thin rim around a piece.

FLASK (n): A box made of two or more parts for holding the sand in a sand molding.

FLUTE (n): Groove as on twist drills, reamers, and taps.

FORGE (v): To force metal while it is hot to take on a desired shape by hammering or pressing.

GALVANIZE (v): To cover a surface with a thin layer of molten alloy composed mainly of zinc to prevent rusting.

GASKET (n): A thin piece of rubber, metal, or some other material placed between surfaces to make a tight joint.

GATE (n): The opening in a sand mold at the bottom of the sprue through which the molten metal passes to enter the cavity or mold.

GRADUATE (v): To set off accurate divisions on a scale or dial.

GRIND (v): To remove metal by means of an abrasive wheel often made of carborundum; used chiefly where accuracy is required.

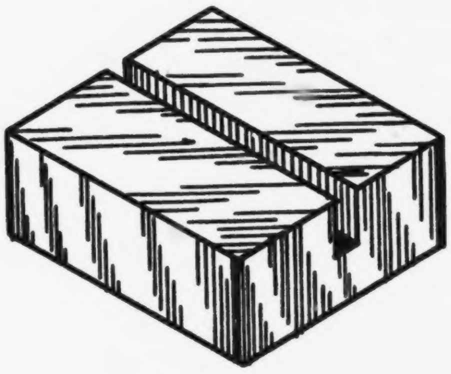
HARDEN (v): To heat steel above a critical temperature and then quench in water or oil.

HEAT TREAT (v): To change the properties of metals by heating and then cooling.

INTERCHANGEABLE (adj): Refers to a part made to limit dimensions so that it will fit any mating part similarly manufactured.

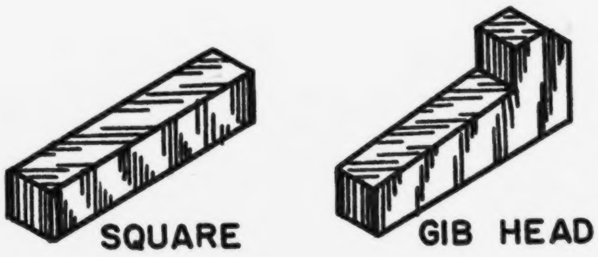
JIG (n): A device for guiding a tool in cutting a piece. Usually holds the work in position.

JOURNAL (n): Portion of a rotating shaft supported by a bearing.



KERF

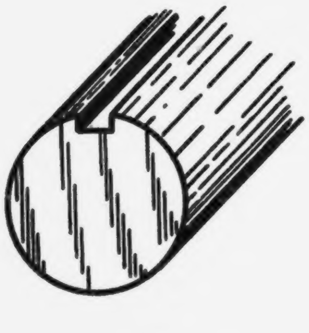
KERF (n): Groove or cut made by a saw.



SQUARE GIB HEAD

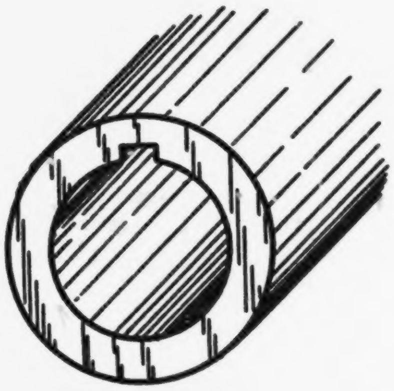
KEYS

KEY (n): A small piece of metal sunk partly into both shaft and hub to prevent rotation.



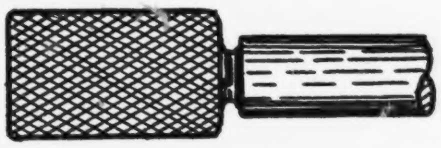
KEYSEAT

KEYSEAT (n): A slot or recess in a shaft to hold a key.



KEYWAY

KEYWAY (n) A slot in a hub or portion surrounding a shaft to receive a key.

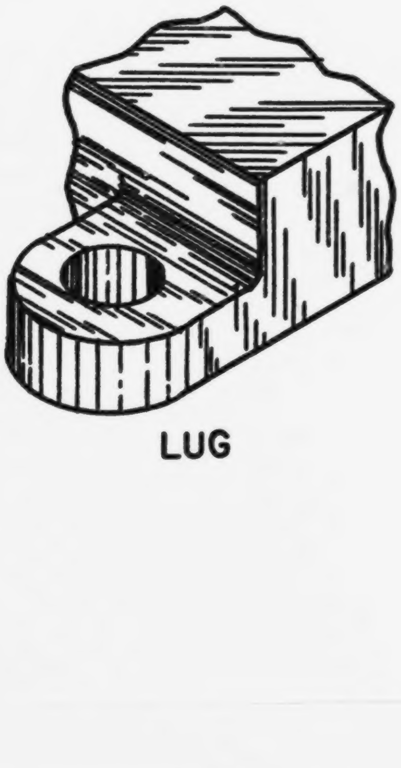


KNURL

KNURL (v): To impress a pattern of dents in a turned surface with a knurling tool to produce a better hand grip.

LAP (v): To produce a very accurate finish by sliding contact with a lap or piece of wood, leather, or soft metal impregnated with abrasive powder.

LATHE (n): A machine used to shape metal or other materials by rotating the material against a tool.



LUG

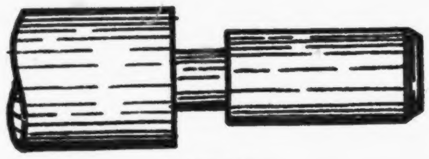
LUG (n): An irregular projection of metal but not round as in the case of a boss; usually with a hole in it for a bolt or screw.

MALLEABLE CASTING (n): A casting which has been made less brittle and tougher by annealing.

MILL (v): To remove material by means of a rotating cutter on a milling machine.

MOLD (n): The mass of sand or other material which forms the cavity into which molten metal is poured.

MS (n): Machinery steel, sometimes called mild steel with a small percentage of carbon. Cannot be hardened.

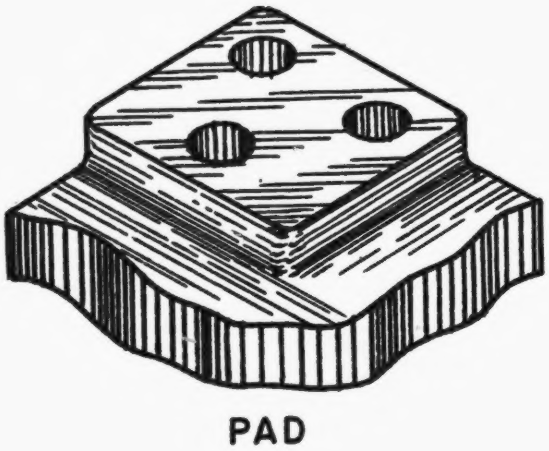


NECK

NECK (v): To cut a groove called a neck around a cylindrical piece.

NORMALIZE (v): To heat steel above its critical temperature and then cool it in air.

PACK HARDEN (v): To carburize, then to case harden.



PAD

PAD (n): A slight projection, usually to provide a bearing surface around one or more holes.

PATTERN (n): A model usually of wood used in forming a mold for a casting. In sheet metal work, a pattern is called a "development."

PEEN (v): To hammer into shape with a ballpeen hammer.

PICKLE (v): To clean forgings or castings in dilute sulphuric acid.

PINION (n): The smaller of two mating gears.

PITCH CIRCLE (n): An imaginary circle corresponding to the circumference of the friction gear from which the spur gear was derived.

PLANE (v): To remove material by means of the planer.

PLANISH (v): To impart a planished surface to sheet metal by hammering with a smooth-surfaced hammer.

PLATE (v): To coat a metal piece with another metal, such as chrome or nickel, by electrochemical methods.

POLISH (v): To produce a highly finished or polished surface by friction, using a very fine abrasive.

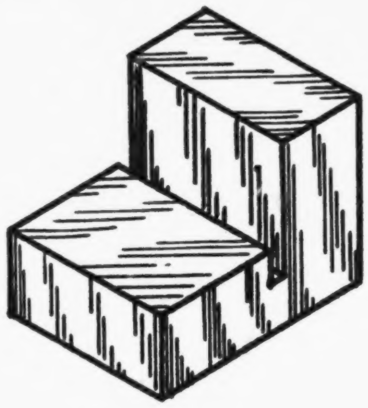
PROFILE (v): To cut any desired outline by moving a small rotating cutter, usually with a master template as a guide.

PUNCH (v): To cut an opening of a desired shape with a rigid tool having the same shape by pressing the tool through the work.

QUENCH (v): To immerse a heated piece of metal in water or oil in order to harden it.

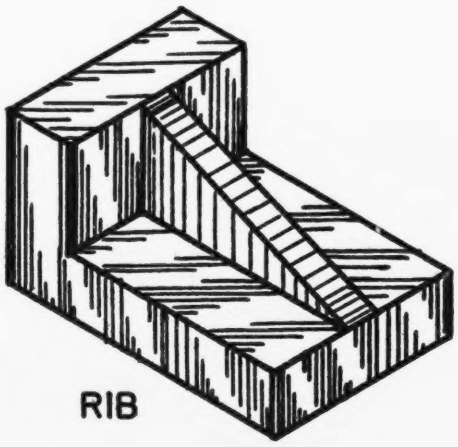
RACK (n): A flat bar with gear teeth in a straight line to engage with teeth in a gear.

REAM (v): To enlarge a finished hole slightly to give it greater accuracy with a reamer.



RELIEF

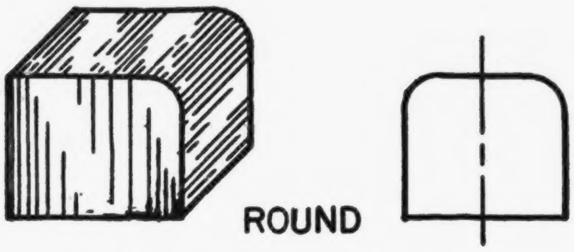
RELIEF (n): An offset of surfaces to provide clearance for machining.



RIB

RIB (n): A relatively thin flat member acting as a brace or support.

RIVET (v): To connect with rivets or to clench over the end of a pin by hammering.



ROUND

ROUND (n): An exterior rounded intersection of two surfaces.

SAE: Society of Automotive Engineers.

SANDBLAST (v): To blow sand at high velocity with compressed air against castings or forgings to clean them.

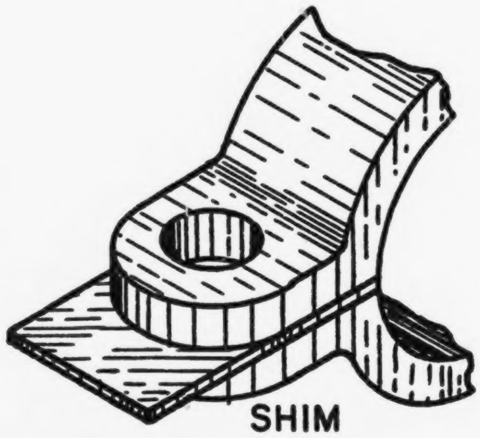
SCLEROSCOPE (n): An instrument for measuring hardness of metals.

SCRAPE (v): To remove metal by scraping with a hand scraper, usually to fit a bearing.

SHAPE (v): To remove metal from a piece with a shaper.

SHEAR (v): To cut metal by means of shearing with two blades in sliding contact.

SHERARDIZE (v): To galvanize a piece with a coating of zinc by heating it in a drum with zinc powder to a temperature of 575° to 850° F.

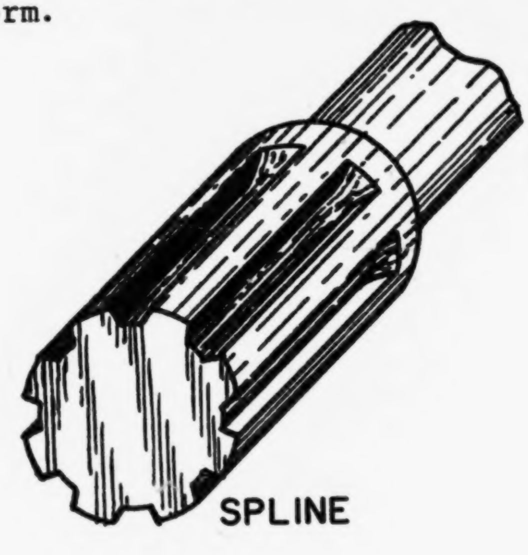


SHIM

SHIM (n): A thin piece of metal or other material used as a spacer in adjusting two parts.

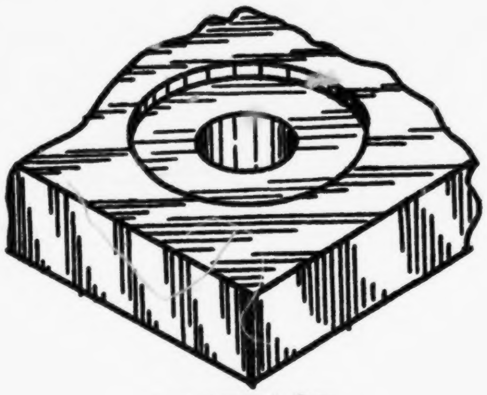
SOLDER (v): To join with solder usually composed of lead or tin.

SPIN (v): To form a rotating piece of sheet metal into a desired shape by pressing it with a smooth tool against a rotating form.



SPLINE

SPLINE (n): A keyway, usually one of a series cut around a shaft or hole.



SPOTFACE

SPOTFACE (v): To produce a round spot or bearing surface around a hole, usually with a spotfacer. The spotface may be on top of a boss or it may be sunk into the surface.

SPRUE (n): A hole in the sand leading to the gate which leads to the mold, through which the metal enters.

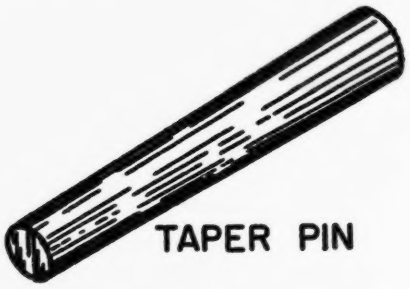
STEEL CASTING (n): Like cast iron casting except that in the furnace scrap steel has been added to the casting.

SWAGE (v): To hammer metal into shape while it is held over a swage or die which fits in a swage block or anvil.

SWEAT (v): To fasten metal together by the use of solder between the pieces and by the application of heat and pressure.

TAP (v): To cut relatively small internal threads with a tap.

TAPER (n): Conical form given to a shaft or a hole. Also refers to the slope of a plane surface.



TAPER PIN

TAPER PIN (n): A small tapered pin for fastening, usually to prevent a collar or hub from rotating on a shaft.

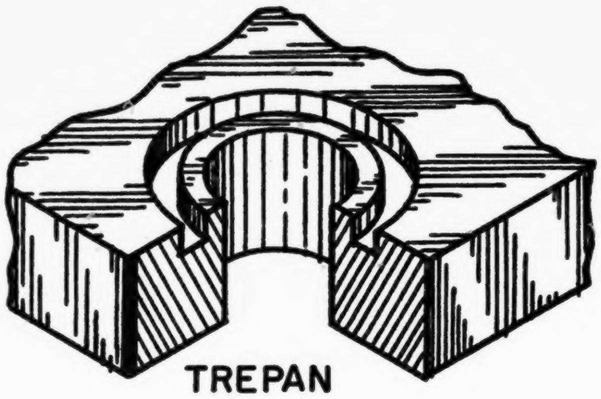
TAPER REAMER (n): A tapered reamer for producing accurate tapered holes as for a taper pin.

TEMPER (v): To reheat hardened steel to bring it to a desired degree of hardness.

TEMPLATE OR TEMPLET (n): A guide or pattern used to mark out the work, guide the tool in cutting it, or check the finished product.

TIN (n): A silvery metal used in alloys and for coating other metals such as tin plate.

TOLERANCE (n): Total amount of variation permitted in limit dimension of a part.



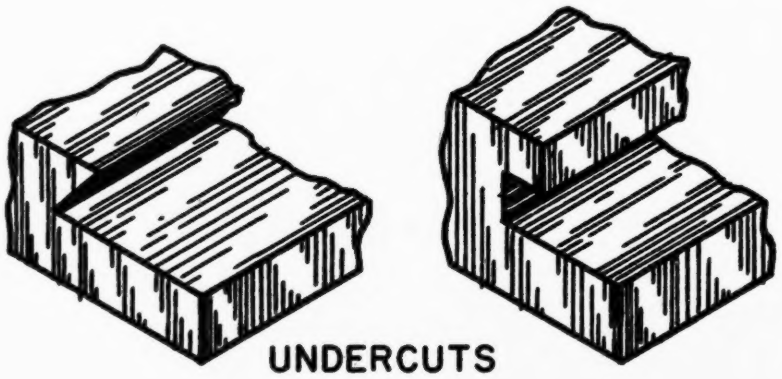
TREPAN

TREPAN (v): To cut a circular groove in the flat surface at one end of a hole.

TUMBLE (v): To clean rough castings or forgings in a revolving drum filled with scrap metal.

TURN (v): To produce on a lathe a cylindrical surface parallel to the center line.

TWIST DRILL (n): A drill for use in a drill press.



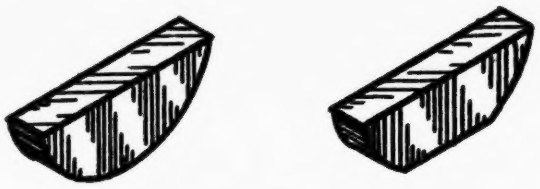
UNDERCUTS

UNDERCUT (n): A recessed cut or a cut with inwardly sloping sides.

UPSET (v): To form a head or enlarged end on a bar or rod by pressure or by hammering between dies.

WEB (n): A thin flat part joining larger parts. Also known as a rib.

WELD (v): Uniting metal pieces by pressure or fusion welding processes.



WOODRUFF KEYS

WOODRUFF KEY (n): A semicircular flat key.

WROUGHT IRON (n): Iron of low carbon content useful because of its toughness, ductility, and malleability.

UNIT IV - WORKING DRAWING INTERPRETATION

Tolerance Dimensions

Lesson 3

OBJECTIVES:

1. To define basic terms related to tolerance dimensions.
2. To describe basic applications of tolerancing on working drawings.

REFERENCE:

1. Chapter 12, TECHNICAL DRAWING, Giesecke, Mitchell, and Spencer.

INFORMATION:

As can be seen through a brief study of shop processes, accuracy of specification concerning the applications of size to the relationships of designed parts is quite important. The specification of a single unvariable dimension on working drawings in many cases is a hindrance to sound machine shop practice.

Reasons for this include:

1. Slight variance of dimensional limits will occur in mass production operations as a result of tool wear.
2. In order to economically manufacture mass produced parts, built-in tolerances have to be provided. This also assures that replacement parts will operate well with original parts on many products.
3. It is impossible under even the best conditions to produce any part to exact size.
4. Extreme accuracy in manufacture becomes costly and almost prohibitive in many cases. For example, if parts for a baby carriage were made to "jet engine accuracy", neither the manufacturer nor the buyer could long bear the expense.

Therefore, according to the tolerance of accuracy required by various operations and to suit the needs of a particular manufacturer, various "classes of fit" and degrees of tolerance have been outlined by the American Standards Association (ASA). See Appendix Tables 3-9.

These classes of tolerances are referenced on drawings by the draftsman who must know when to specify a definite tolerance and how to represent it pictorially.

In your title block you have already specified a tolerance for all working drawing dimensions. You have stated that the machinist may vary a limited amount from the dimensions you have placed on your drawings.

EXAMPLE:

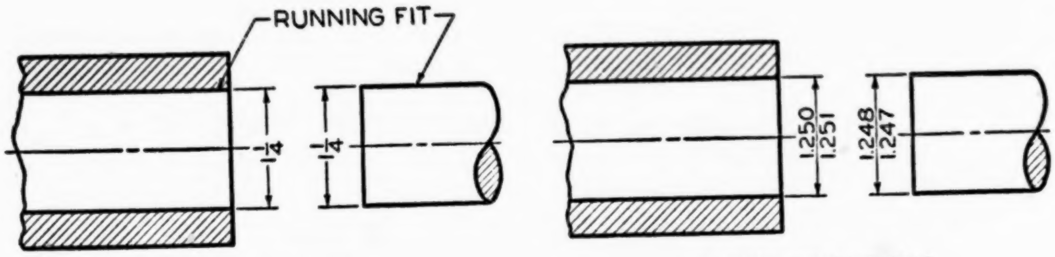
Given - a 2 PL decimal with limits of ±.02
Calculate - the upper and lower limits of the dimension .50"
Solution - the size of the part may be made between .48" and .52"

EXAMPLE:

Given - a 3 PL decimal with limits of ±.005
Calculate - the upper and lower limits of the dimension .750
Solution - the size of the part may be made between .745" and .755"

Specification of tolerance in the title block or elsewhere on the drawing according to the desired or permissible limits of variance is necessary. A built-in variable must be assumed for all dimensions. Neither the machinist nor the most accurate machine is perfect in every respect.

Remember that when specifying closer tolerances for parts, they cost more to manufacture. Specify the most generous tolerance permissible for the designed part which will still permit satisfactory functioning of the part.



(a) OLD METHOD

(b) LIMIT DIMENSIONS

Fits between Mating Parts.

Figure 1.

In the past it was possible to specify nominal dimensions for two mating parts by means of common fractions, including a note for the type of fit desired. Accuracy in this case depended upon the skill of the workman.

In order that parts could be made interchangeable on a mass production basis, tolerances had to be specified.

When parts are made to fit together properly in an isolated assembly situation and not be interchangeable with similar parts, the size of one part only need be toleranced. In this case a note is included indicating fit at assembly.

Definition of Terms

The following are terms used in connection with tolerancing. Learn what they mean and develop a working knowledge of their applications.

NOMINAL SIZE - a close approximation to a standard size without any specified tolerance,used for the purpose of general identification. In figure 1b the nominal size of both hole and shaft is $1\frac{1}{4}$".

BASIC SIZE - the "size from which limits of size are derived by the application of allowances and tolerances." It is the exact theoretical size from which limits are figured. In figure 1b the basic size is the decimal equivalent of the nominal size, $1\frac{1}{4}$" or 1.250".

DESIGN SIZE - the "size from which the limits of size are derived by the application of tolerances. When there is no allowance, the design size is the same as the basic size." In figure 1b the design size of the hole is 1.250" (smallest hole) and of the shaft is 1.248" (largest shaft).

TOLERANCE - "the total permissible variation of a size or the difference between the limits."

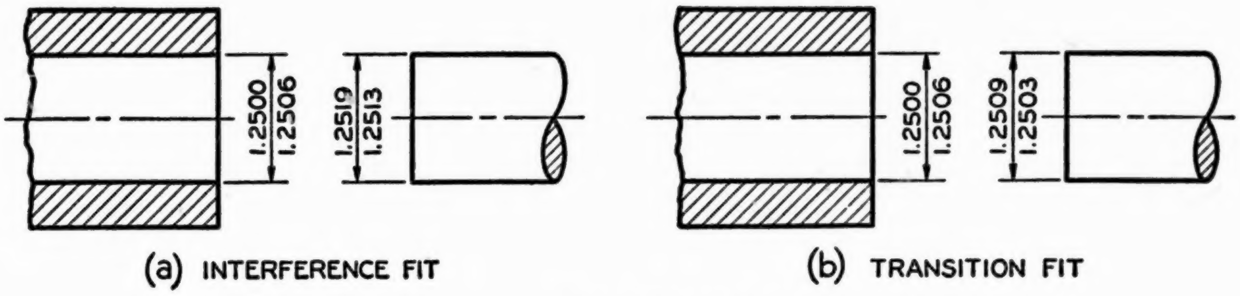
LIMITS - the maximum and minimum sizes indicated by a toleranced dimension.

ALLOWANCE - the minimum clearance space (or maximum interference) intended between mating parts. Allowance, then, represents the tightest permissible fit and is simply the smallest hole minus the largest shaft. For clearance fits this difference will be positive, while for interference fits it will be negative.

Fits Between Mating Parts

The three general types of fits between parts are:

1. CLEARANCE FIT-in which an internal member fits in an external member (as a shaft in a hole) and leaves an air space or clearance between the parts. In figure 1b the largest shaft is 1.248" and the smallest hole is 1.250",which permits a minimum air space of .002" between the parts. This space is the allowance, and in this case it is positive.



(a) INTERFERENCE FIT (b) TRANSITION FIT

Fits Between Parts.

Figure 2.

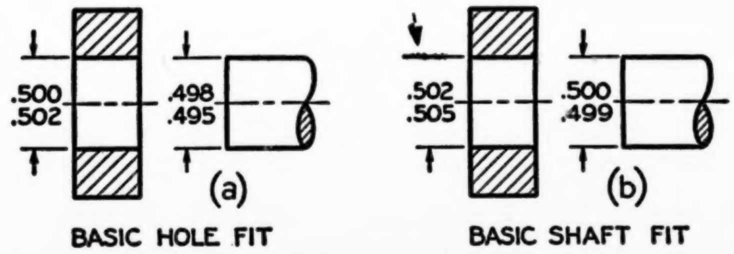
2. INTERFERENCE FIT-in which the internal member is larger than the external member so that there is an actual interference of metal. In figure 2a the smallest shaft is 1.2513" and the largest hole is 1.2506",so that there is an actual interference of metal amounting to at least .0007".

3. TRANSITION FIT-in which the fit might be either a clearance fit or an interference fit. In figure 2b the smallest shaft, 1.2503", will fit in the largest hole, 1.2506", with .0003" to spare. But the largest shaft, 1.2503", will have to be forced into the smallest hole, 1.2500", with an interference of metal (negative allowance) of .0009".

Basic Hole System

Standard reamers, broaches, and other standard tools are often used to produce holes; and standard plug gages are used to check the actual sizes. On the other hand, shafting can easily be machined to any size desired. Therefore, toleranced dimensions are most commonly figured on the so-called BASIC HOLE SYSTEM. In this system the MINIMUM HOLE IS TAKEN AS THE BASIC SIZE, and allowance is assigned, and tolerances are applied on both sides of and away from this allowance.

Figure 3.



BASIC HOLE FIT BASIC SHAFT FIT

Basic Hole and Basic Shaft Systems.

In figure 3a the minimum size of the hole (.500") is taken as the basic size. An allowance of .002" is decided upon and subtracted from the basic hole size,giving the maximum shaft .498". Tolerances of .002" and .003",respectively, are applied to the hole and shaft to obtain the maximum hole of .502" and the minimum shaft of .495". Thus the minimum clearance between the parts is .500" - .498" = .002" (smallest hole minus largest shaft), and the maximum clearance is .502" - .495" = .007" (largest hole minus smallest shaft).

In the case of an interference fit, the maximum shaft size would be found by ADDING THE DESIRED ALLOWANCE (maximum interference) to the basic hole size. In figure 2a the basic size is 1.2500". The maximum interference decided upon was .0019", which added to the basic size gives 1.2519", the largest shaft size.

The basic hole size can be changed to the basic shaft size by subtracting the allowance for a clearance fit or adding it for an interference fit. The result is the largest shaft size,which is the new basic size.

Basic Shaft System

In some branches of industry, such as textile machinery manufacturing in which use is made of a great deal of cold-finished shafting, the BASIC SHAFT SYSTEM is often used. This system should be used only when there is a reason for it. For example, it is advantageous when several parts having different fits, but one nominal size, are required on a single shaft. In this system THE MAXIMUM SHAFT IS TAKEN AS THE BASIC SIZE, an allowance for each mating part is assigned, and tolerances are applied on both sides of and away from this allowance.

In figure 3b the maximum size of the shaft (.500") is taken as the basic size. An allowance of .002" is decided upon and added to the basic shaft size,giving the minimum hole .502". Tolerances of .003" and .001", respectively, are applied to the hole and shaft to obtain the maximum hole (.505") and the minimum shaft (.499"). Thus the minimum clearance between the parts is .502" - .500" = .002" (smallest hole minus largest shaft), and the maximum clearance is .505" - .499" = .006" (largest hole minus smallest shaft).

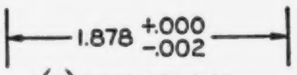
In the case of an interference fit, the minimum hole size would be found by SUBTRACTING THE DESIRED ALLOWANCE FROM THE BASIC SHAFT SIZE.

The basic shaft size may be changed to the basic hole size by adding the allowance for a clearance fit or subtracting it for an interference fit. The result is the smallest hole size,which is the new basic size.

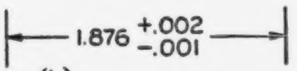
Unilateral Tolerances

A unilateral tolerance allows variations in only one direction from a design size. This method is advantageous when a critical size is approached as material is removed during manufacture, as in the case of close-fitting holes and shafts.

In figure 4a the design is 1.878". The tolerance (.002") is all in one direction--toward a smaller size. If this is a shaft diameter, the design size (1.878") is the size nearest the critical size because it is nearest to the tolerance zone; hence, the tolerance is taken AWAY from the critical size. A unilateral tolerance is always all plus or all minus. That is, either the plus or the minus value must be zero. However, the zeros should not be omitted.



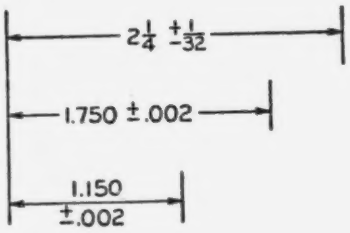
(a) UNILATERAL TOLERANCE



(b) BILATERAL TOLERANCE

Tolerance Expression.

Figure 4.



Bilateral Tolerances.

Figure 5.

Bilateral Tolerances

A bilateral system of tolerances allows variations in both directions from a design size. Bilateral tolerances are usually given with location dimensions or with any dimensions that can be allowed to vary in either direction.

In figure 4b the design size is 1.876", and the actual size may be larger by .002" or smaller by .001". If it is desired to specify an equal variation in both directions, the combined plus or minus symbol (±) is used with a single value as shown in figure 5.

Specification of Tolerances

For fractional dimensions, the worker is not expected to work closer than he can be expected to measure with a steel rule. It is customary to indicate an over-all tolerance for all common fraction dimensions by means of a printed note in or just above the title block, such as ALL FRACTIONAL DIMENSIONS ± .010 UNLESS OTHERWISE SPECIFIED,or HOLD FRACTIONAL DIMENSIONS TO ± $\frac{1}{64}$ UNLESS OTHERWISE NOTED. General angular tolerances also may be given, as ANGULAR TOLERANCE 1^{o}.

General tolerances on decimal dimensions in which tolerances are not given may also be covered in a general printed note, such as DECIMAL DIMENSIONS TO BE HELD TO ± .001. Thus if a dimension 3.250 is given, the worker machines between the limits 3.249 and 3.251. Every dimension on a drawing should have a tolerance either direct or by general tolerance note, except that commercial material is often assumed to have the tolerances set by commercial standards.

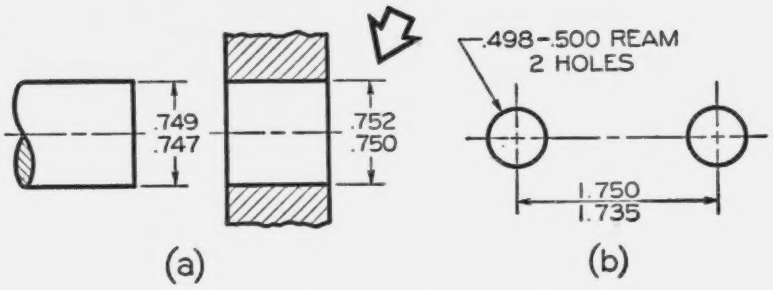
A tolerance of a decimal dimension should be given in decimal form to the same number of places. A tolerance of a dimension given in common-fraction form should be given as a common fraction. (See figure 5.)

Several methods of expressing tolerances in dimensions are approved by ASA, as follows:

1. PLUS AND MINUS. Two unequal tolerance numbers are given, one plus and one minus, with the plus above the minus (figure 4). One of the numbers may be zero, if desired.

2. PLUS OR MINUS. A single tolerance value is given, preceded by the plus or minus symbol (±), (figure 5). This method should be used when the plus and minus values are equal.

3. LIMITS. The maximum and minimum limits of size are specified as shown in figure 6. The high limit is placed above the low limit, thus $\begin{matrix}.749\\.747\end{matrix}$ DIA. In note form, the low limit is given first, thus .498-.500 REAM.



(a) (b)

Method of Giving Limits.

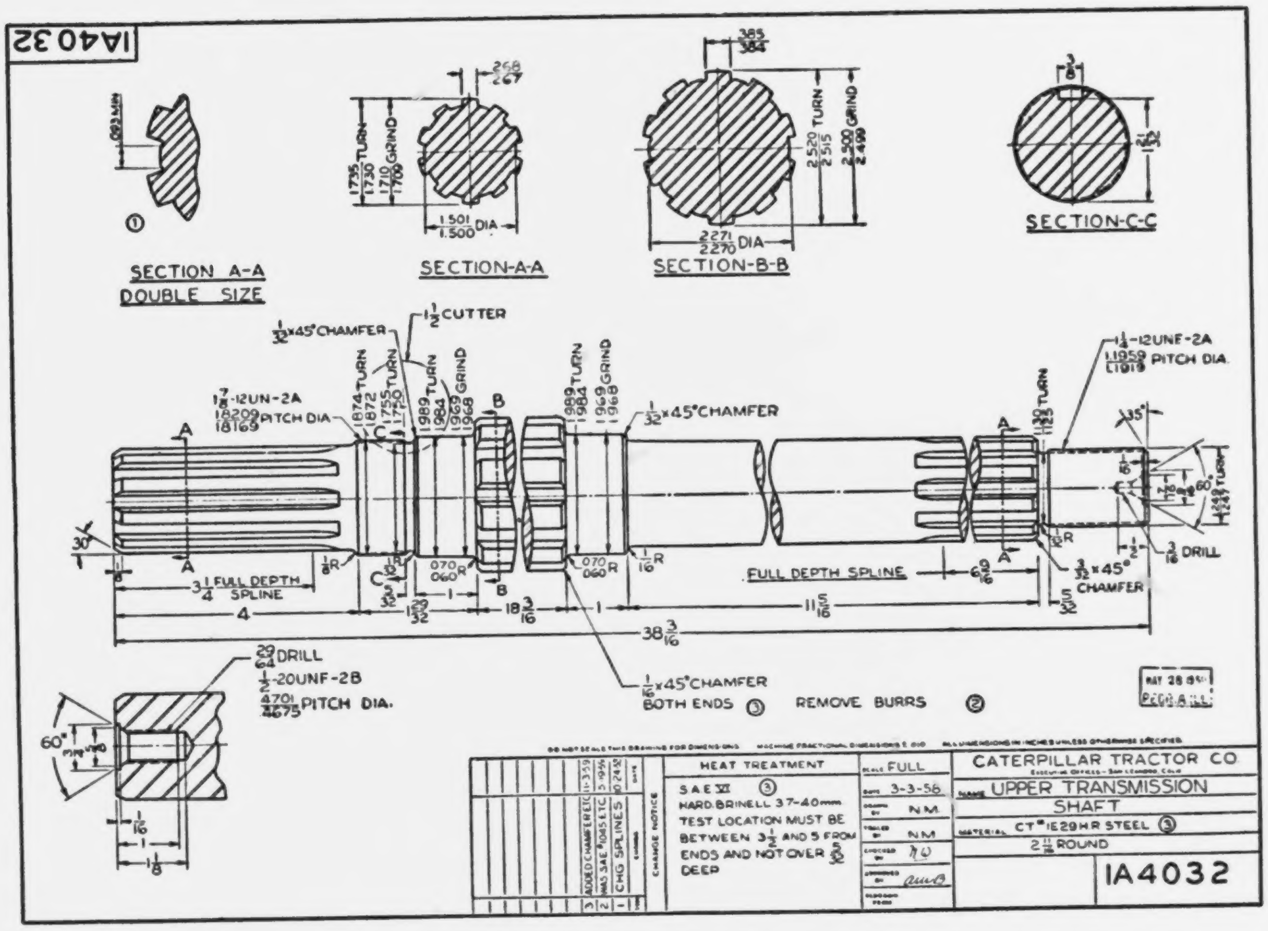
*ASA Y14.5-1957.

Figure 6.

The old method of placing limits is also approved in the new ASA standard. For a shaft, the high limit is placed above the low limit, since a shaft is machined from "large to small." This agrees with the rule above. However, for a hole dimensioned directly (see arrow), the low limit is placed above since a hole is machined from "small to large," thus $\begin{matrix}.750\\.752\end{matrix}$. This is the only difference between the methods. However, the method adopted should be used consistently through a drawing.

A typical example of limit dimensioning is given in figure 7.

4. MIN or MAX is often placed after a number to indicate minimum or maximum dimensions desired. For example, a thread length may be dimensioned thus: |◄—1.500—►| MIN FULL THD, or a radius dimensioned .05 R MAX ——► Other applications include depths of holes and chamfers.


1A4032
SECTION A-A DOUBLE SIZE
SECTION-A-A
SECTION-B-B
SECTION-C-C
1.501/1.500 DIA
2.271/2.270 DIA
1.735/1.730 TURN
1.710/1.700 GRIND
2.520/2.515 TURN
2.500/2.499 GRIND
1/32 x45° CHAMFER
1 1/2 CUTTER
1 7/8-12UN-2A
1.8209/1.8169 PITCH DIA
1 1/4-12UNF-2A
1.1959/1.1919 PITCH DIA
FULL DEPTH SPLINE
3 1/4 FULL DEPTH SPLINE
4
18 3/16
11 5/16
38 3/16
29/64 DRILL
1/2-20UNF-2B
.4701/.4675 PITCH DIA.
1/16 x45° CHAMFER BOTH ENDS ③
REMOVE BURRS ②
HEAT TREATMENT
CATERPILLAR TRACTOR CO
UPPER TRANSMISSION SHAFT
FULL
3-3-56
NM
2 1/16 ROUND
1A4032

Limit Dimensions.

Figure 7.

5. Angular tolerances are usually bilateral and in terms of degrees, minutes, and seconds.
   Examples: $25^{o} \pm 1^{o}$, $25^{o}\ 0' \pm 0^{o}\ 15'$, or $25^{o} \pm .25^{o}$.

American Standard Limits and Fits

There are five types of fit prescribed by the ASA for cylindrical parts. Letter symbols are used to identify them as follows:

RC	Running or sliding fit
LC	Locational clearance fit
LT	Transition fit
LL	Locational interference fit
FN	Force of shrink fit

These letter symbols, plus a number indicating the class of fit within each type, are used to indicate a complete fit. Thus, FN 4 means a Class 4 Force Fit. The fits are described as follows:

Running and Sliding Fits

Running and sliding fits, for which limits of clearance are given in the appendix tables, are intended to provide a similar running performance with suitable lubrication allowance throughout the range of sizes. The clearances for the first two classes, used chiefly as slide fits, increase more slowly with diameter than the other classes so that accurate location is maintained even at the expense of free relative motion. These fits may be described briefly as follows:

RC 1 CLOSE SLIDING FITS are intended for the accurate location of parts which must assemble without perceptible play.

RC 2 SLIDING FITS are intended for accurate location, but with greater maximum clearance than class RC 1. Parts made to this fit move and turn easily but are not intended to run freely, and in the larger sizes may seize with small temperature changes.

RC 3 PRECISION RUNNING FITS are about the closest fits which can be expected to run freely and are intended for precision work at slow speeds and light journal pressures, but are not suitable where appreciable temperature differences are likely to be encountered.

RC 4 CLOSE RUNNING FITS are intended chiefly for running fits on accurate machinery with moderate surface speeds and journal pressures, where accurate location and minimum play is desired.

RC 5 MEDIUM RUNNING FITS are intended for higher running speeds or heavy journal pressures.

RC 6 MEDIUM RUNNING FITS are intended for higher running speeds and heavy journal pressures.

RC 7 FREE RUNNING FITS are intended for use where accuracy is not essential or where large temperature variations are likely to be encountered, or under both these conditions.

RC 8
RC 9 LOOSE RUNNING FITS are intended for use where materials such as cold-rolled shafting and tubing, made to commercial tolerances, are involved.

Locational Fits

Locational fits (see appendix) are fits intended to determine only the location of the mating parts. They may provide rigid or accurate location, as with interference fits, or provide some freedom of location, as with clearance fits. Accordingly, they are divided into three groups: clearance fits, transition fits, and interference fits. These are more fully described as follows:

LC LOCATIONAL CLEARANCE FITS are intended for parts which are normally stationary but which can be freely assembled or disassembled. They run from snug fits for parts requiring accuracy of location, through the medium clearance fits for parts such as spigots, to the looser fastener fits where freedom of assembly is of prime importance.

LT TRANSITION FITS are a compromise between clearance and interference fits, for application where accuracy of location is important, but either a small amount of clearance or interference is permissible.

LN LOCATIONAL INTERFERENCE FITS are used where accuracy of location is of prime importance, and for parts requiring rigidity and alignment with no special requirements for bore pressure. Such fits are not intended for parts designed to transmit frictional loads from one part to another by virtue of the tightness of fit.

Force Fits

Force or shrink fits (see appendix) constitute a special type of interference fit normally characterized by maintenance of constant bore pressures throughout the range of sizes. The interference, therefore, varies almost directly with diameter, and the difference between its minimum and maximum value is small to maintain the resulting pressures within reasonable limits. These fits may be described as follows:

FN 1 LIGHT DRIVE FITS are those requiring light assembly pressures, and produce more or less permanent assemblies. They are suitable for thin sections or long fits or in cast iron external members.

FN 2 MEDIUM DRIVE FITS are suitable for ordinary steel parts or for shrink fits on light sections. They are about the tightest fits that can be used with high-grade cast iron external members.

FN 3 HEAVY DRIVE FITS are suitable for heavier steel parts or for shrink fits in medium sections.

FN 4 FORCE FITS are suitable for parts which can be highly
FN 5 stressed or for shrink fits where the heavy pressing forces required are impractical.

In the tables for each class of fit the range of nominal sizes of shafts or holes is given in inches. To simplify the tables and reduce the space required to present them, the other values are given in thousandths of an inch. Minimum and maximum limits of clearance are given, the top number being the least clearance or the allowance, and the lower number being the maximum clearance or greatest looseness of fit. Then, under the heading "Standard Limits" are given the limits for the hole and for the shaft that are to be applied algebraically to the basic size to obtain the limits of size for the parts.

For example, take a 2.0000" basic diameter with a Class RC 1 fit. This fit is given in Appendix Table #3. In the column headed "Nominal Size Range, Inches", find 1.97-3.15 which embraces the 2.0000" basic size. Reading to the right we find under "Limits of Clearance" the values 0.4 and 1.2 representing the maximum and minimum clearance between the parts IN THOUSANDTHS OF AN INCH. To get these values in inches, simply multiply by one thousandth, thus $\frac{4}{10} \times \frac{1}{1000} =$ .0004. Or, to convert 0.4 thousandths to inches, simply move the decimal point three places to the left, thus .0004". Therefore, for this 2.0000" diameter with a Class RC 1 fit, the minimum clearance or allowance is .0004"; and the maximum clearance, representing the greatest looseness, is .0012".

Reading farther to the right we find under "Standard Limits" the value +0.5, which converted to inches is .0005". Add this to the basic size thus: 2.0000" + .0005" = 2.0005", the upper limit of the hole. Since the other value given for the hole is zero, the lower limit of the hole is the basic size of the hole, or 2.0000". The hole would then be dimensioned as follows:

$$\begin{matrix} 2.0000 \\ 2.0005 \end{matrix} \quad \text{or} \quad 2.0000 \begin{matrix} +.0005 \\ -.0000 \end{matrix}$$

The limits for the shaft are read as -.0004" and -.0007". To get the limits of the shaft, subtract these values from the basic size thus:

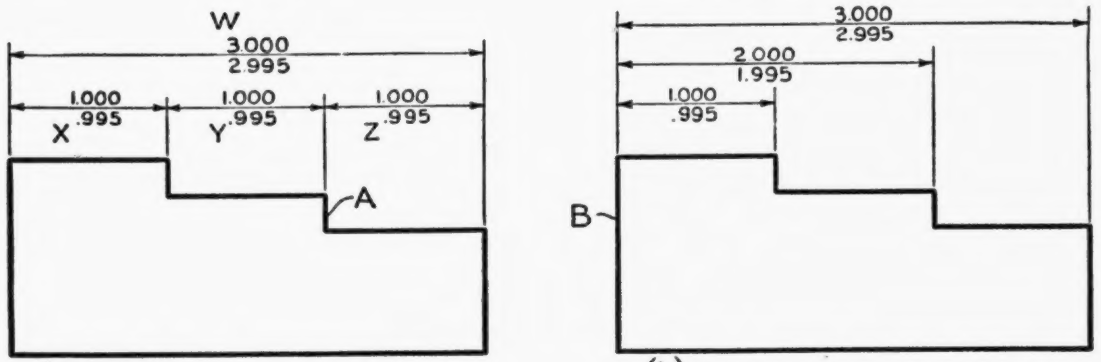
2.0000" - .0004" = 1.9996", the upper limit of the shaft
2.0000" - .0007" = 1.9993", the lower limit of the shaft

The shaft would then be dimensioned as:

$$\begin{matrix} 1.9996 \\ 1.9993 \end{matrix} \quad \text{or} \quad 1.9996 \begin{matrix} +.0000 \\ -.0003 \end{matrix}$$

Accumulation of Tolerances

In limit dimensioning it is very important to consider the effect of one tolerance on another. When the location of a surface in a given direction is affected by more than one tolerance figure, the tolerances are CUMULATIVE. For example, in figure 8a, if dimension "Z" is omitted, surface "A" would be controlled by both dimensions "X" and "Y", and there would be a total variation of .010 instead of the variation of .005 permitted by dimension "Y", which is the dimension directly applied to surface "A". If the part is made to all the minimum tolerances of "X", "Y", and "Z" without regard to the overall length, the overall dimension should be marked "REF." In other cases it may be desired to hold two small dimensions, X and Y, and the overall closely without regard to dimension Z. In that case, dimension Z should be omitted or marked "REF."



(a) CUMULATIVE TOLERANCES (b) BASE-LINE DIMENSIONING

Cumulative Tolerances.

Figure 8.

As a rule it is best to dimension each surface so that it is affected by only one dimension. This can be done by referring all dimensions to a single datum surface, such as B as shown at figure 8b.

Geometric Tolerances

GEOMETRIC TOLERANCE, or "tolerance of form", specifies "how far actual surfaces are permitted to vary from the perfect geometry implied by drawings." The term "geometric" refers to the various geometric forms, as a plane, a cylinder, a cone, a square, or a hexagon. Theoretically, these are perfect forms; but, since it is impossible to produce perfect forms, it may be necessary to specify the amount of variation permitted. Geometric tolerances define conditions of straightness, flatness, parallelism, squareness, angularity, symmetry, concentricity, and roundness.

Methods of indicating geometric tolerances by means of notes, as recommended by ASA (Y14.5-1957), are shown in figures 9 and 10. At the right of each example the meaning of the tolerance note or dimension is illustrated. In these examples tolerances of form are considered individually, not taking into account the effects of combinations with other tolerances of position, size, or form.

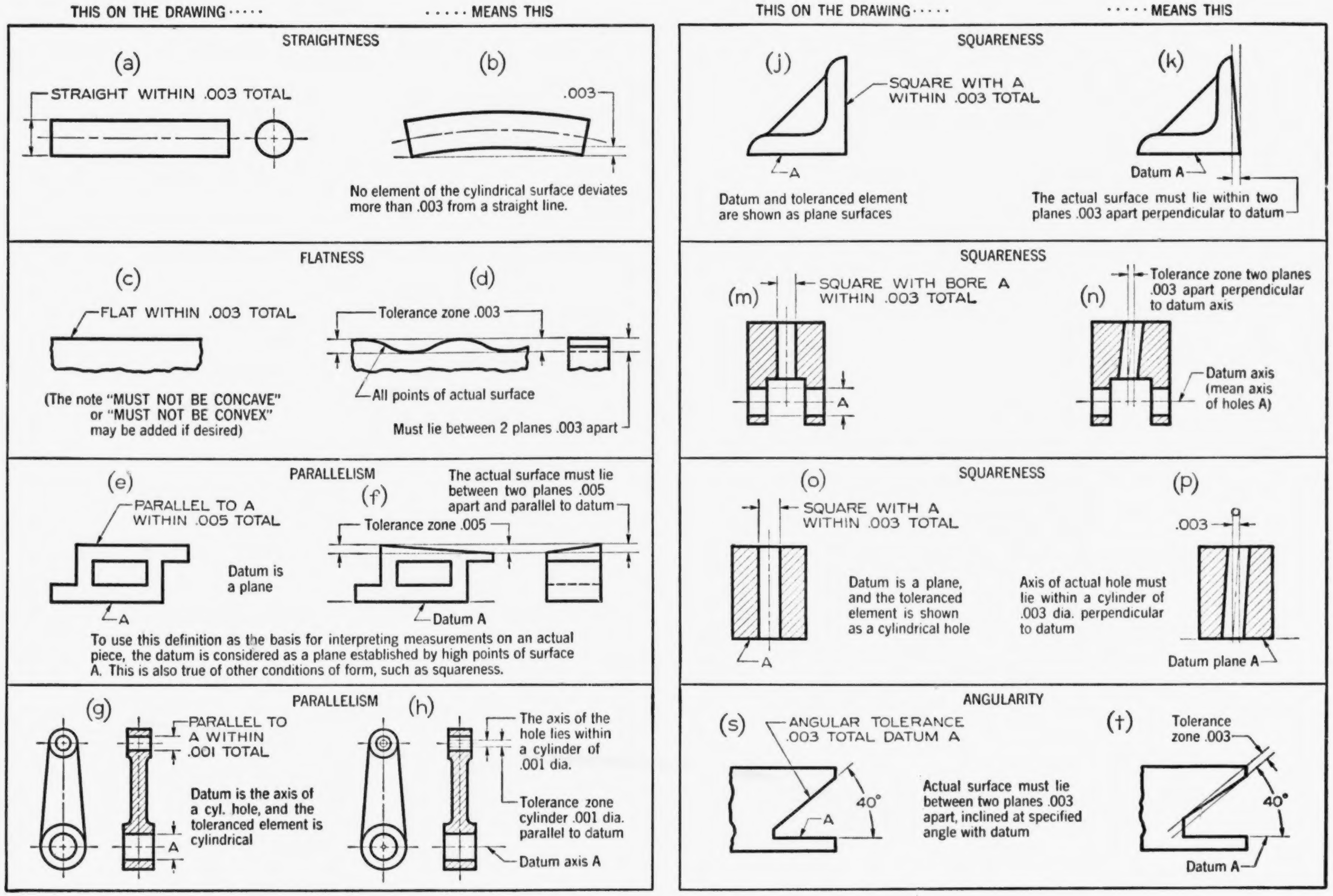

THIS ON THE DRAWING·····
·····MEANS THIS
STRAIGHTNESS
(a)
STRAIGHT WITHIN .003 TOTAL
(b)
.003
No element of the cylindrical surface deviates more than .003 from a straight line.
FLATNESS
(c)
FLAT WITHIN .003 TOTAL
(The note "MUST NOT BE CONCAVE" or "MUST NOT BE CONVEX" may be added if desired)
(d)
Tolerance zone .003
All points of actual surface
Must lie between 2 planes .003 apart
PARALLELISM
(e)
PARALLEL TO A WITHIN .005 TOTAL
A
Datum is a plane
(f)
The actual surface must lie between two planes .005 apart and parallel to datum
Tolerance zone .005
Datum A
To use this definition as the basis for interpreting measurements on an actual piece, the datum is considered as a plane established by high points of surface A. This is also true of other conditions of form, such as squareness.
PARALLELISM
(g)
PARALLEL TO A WITHIN .001 TOTAL
A
Datum is the axis of a cyl. hole, and the toleranced element is cylindrical
(h)
The axis of the hole lies within a cylinder of .001 dia.
Tolerance zone cylinder .001 dia. parallel to datum
Datum axis A
THIS ON THE DRAWING·····
·····MEANS THIS
SQUARENESS
(j)
SQUARE WITH A WITHIN .003 TOTAL
A
Datum and toleranced element are shown as plane surfaces
(k)
Datum A
The actual surface must lie within two planes .003 apart perpendicular to datum
SQUARENESS
(m)
SQUARE WITH BORE A WITHIN .003 TOTAL
A
(n)
Tolerance zone two planes .003 apart perpendicular to datum axis
Datum axis (mean axis of holes A)
SQUARENESS
(o)
SQUARE WITH A WITHIN .003 TOTAL
A
Datum is a plane, and the toleranced element is shown as a cylindrical hole
(p)
.003
Axis of actual hole must lie within a cylinder of .003 dia. perpendicular to datum
Datum plane A
ANGULARITY
(s)
ANGULAR TOLERANCE .003 TOTAL DATUM A
A
40°
Actual surface must lie between two planes .003 apart, inclined at specified angle with datum
(t)
Tolerance zone .003
40°
Datum A

Figure 9. **Tolerances of Form** (ASA Y14.5-1957).

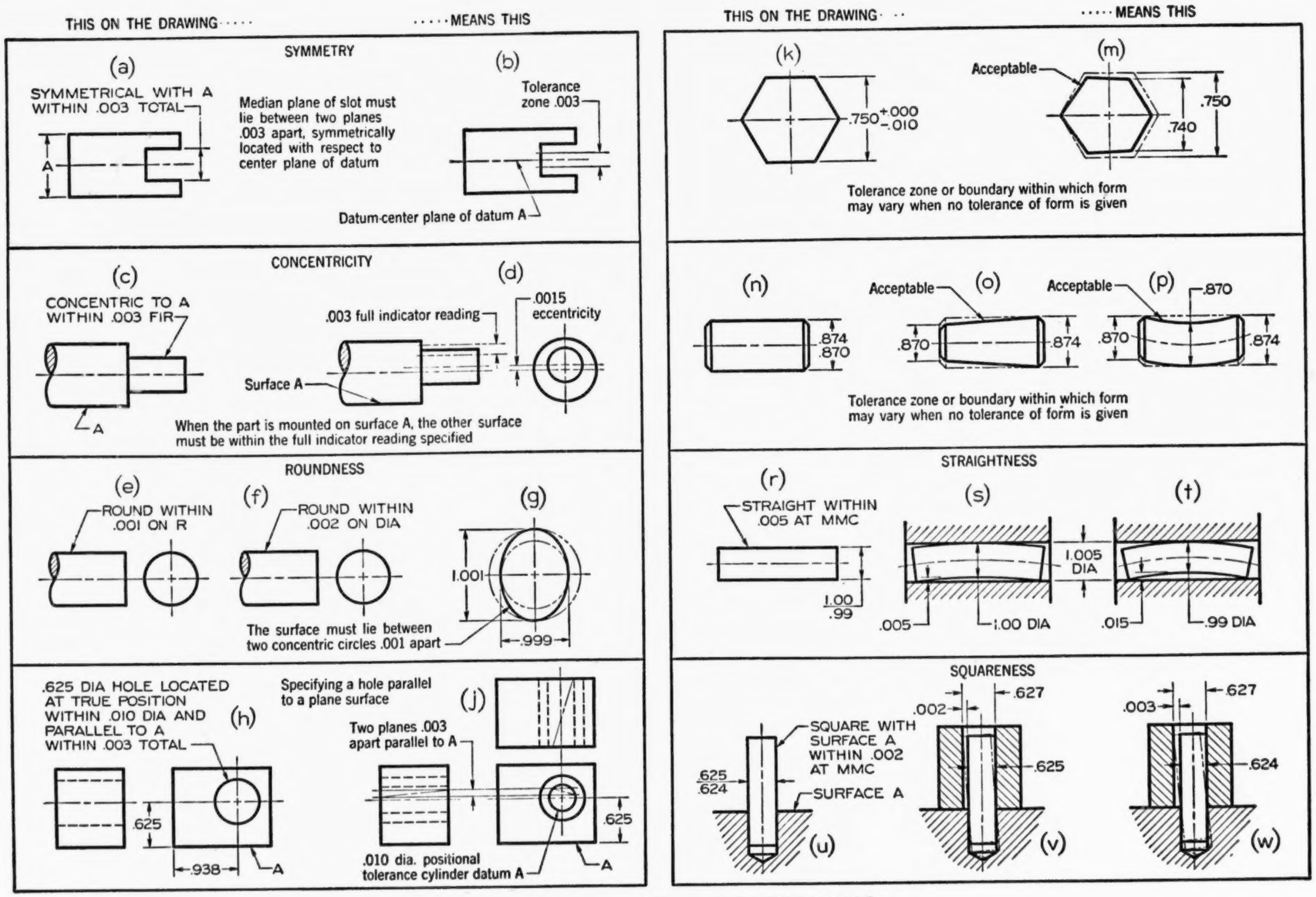
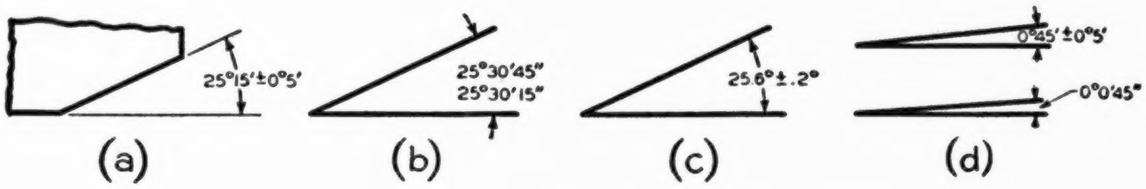

THIS ON THE DRAWING·····
·····MEANS THIS
SYMMETRY
(a)
SYMMETRICAL WITH A WITHIN .003 TOTAL
A
Median plane of slot must lie between two planes .003 apart, symmetrically located with respect to center plane of datum
(b)
Tolerance zone .003
Datum-center plane of datum A
CONCENTRICITY
(c)
CONCENTRIC TO A WITHIN .003 FIR
A
(d)
.003 full indicator reading
.0015 eccentricity
Surface A
When the part is mounted on surface A, the other surface must be within the full indicator reading specified
ROUNDNESS
(e)
ROUND WITHIN .001 ON R
(f)
ROUND WITHIN .002 ON DIA
(g)
1.001
.999
The surface must lie between two concentric circles .001 apart
.625 DIA HOLE LOCATED AT TRUE POSITION WITHIN .010 DIA AND PARALLEL TO A WITHIN .003 TOTAL
(h)
.625
.938
A
Specifying a hole parallel to a plane surface
(j)
Two planes .003 apart parallel to A
.625
.010 dia. positional tolerance cylinder datum A
A
THIS ON THE DRAWING···
·····MEANS THIS
(k)
.750 +.000 -.010
(m)
Acceptable
.740
.750
Tolerance zone or boundary within which form may vary when no tolerance of form is given
(n)
.874
.870
Acceptable
(o)
.870
.874
Acceptable
(p)
.870
.870
.874
Tolerance zone or boundary within which form may vary when no tolerance of form is given
STRAIGHTNESS
(r)
STRAIGHT WITHIN .005 AT MMC
1.00
.99
(s)
.005
1.00 DIA
1.005 DIA
(t)
.015
.99 DIA
SQUARENESS
.625
.624
SQUARE WITH SURFACE A WITHIN .002 AT MMC
SURFACE A
(u)
.002
.627
.625
(v)
.003
.627
.624
(w)

Figure 10. **Tolerances of Form** (ASA Y14.5-1957).

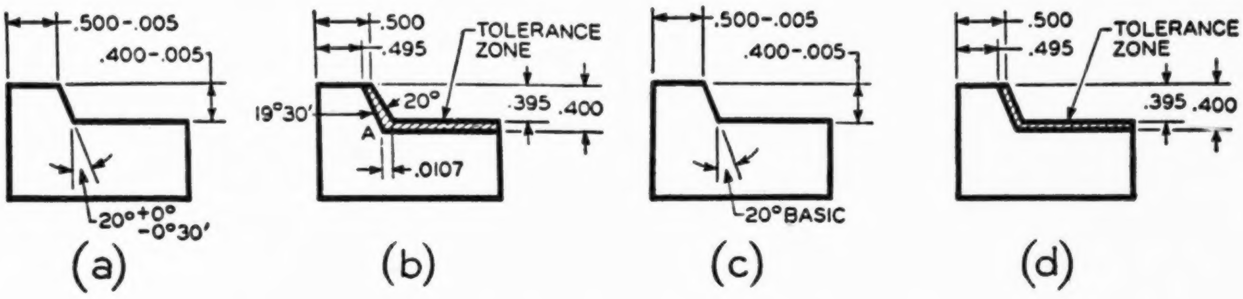
Tolerances of Angles


25°15'±0°5'
25°30'45"
25°30'15"
25.6°±.2°
0°45'±0°5'
0°0'45"
(a)
(b)
(c)
(d)

Tolerances of Angles (ASA Y14.5-1957).

Figure 11.

Bilateral tolerances are usually given on angular dimensions where accuracy must be maintained,as illustrated in figure 11. In figuring tolerances on angles, it should be kept in mind that the width of the tolerance zone increases as the distance from the vertex of the angle increases. The tolerance should be figured after considering the total allowable displacement at the point farthest from the vertex of the angle, and a tolerance specified that will not exceed this. The use of angular tolerances may be avoided by using gages. Taper turning is often handled by machining to fit a gage or by fitting to the mating part.


.500-.005
.400-.005
20°+0°
-0°30'
.500
.495
TOLERANCE ZONE
19°30'
20°
A
.0107
.395
.400
.500-.005
.400-.005
20°BASIC
.500
.495
TOLERANCE ZONE
.395
.400
(a)
(b)
(c)
(d)

Angular Tolerance Zones (ASA Y14.5-1957).

Figure 12.

If an angular surface is located by a linear and an angular dimension (figure 12a), the surface must lie within a tolerance zone as shown at 12b. The angular zone will be wider as the distance from the vertex increases. In order to avoid the accumulation of tolerances, i. e., to decrease the tolerance zone, the BASIC ANGLE tolerancing method (figure 12c) is recommended by the ASA. The angle is marked "BASIC" and no angular tolerance is specified. The tolerance zone is now defined by two parallel planes, resulting in improved angular control (12d). Also see figure 9s-t for tolerancing angularity as tolerance of form.

ASSIGNMENT:

For work assigned from Problems 1 - 8, draw the views of the object necessary to describe the part on size B paper. Follow the system of dimensioning used previously in your work; however, include tolerances for the following:

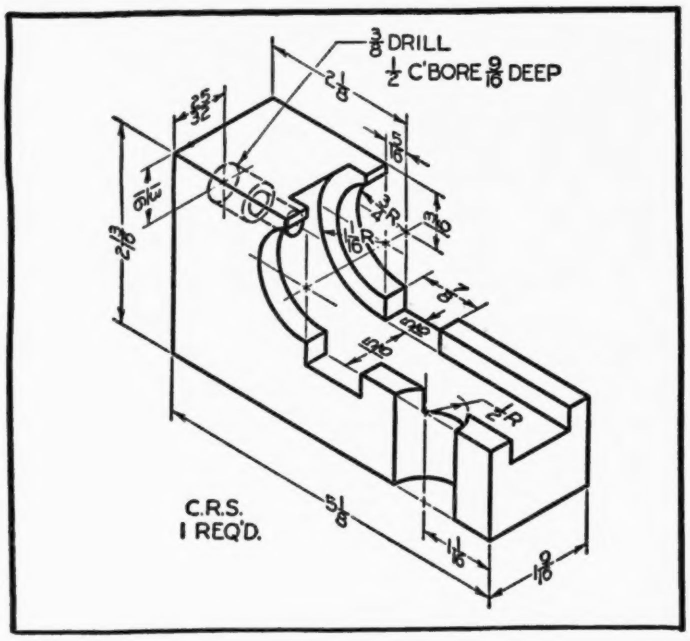
1. bored hole sizes (maintain sizes for drilled holes by single decimal figures).
2. spacing between center lines.
3. location dimension from reference edges.
4. hold all angular tolerances to ($\pm 0^\circ 5'$).

Note. Overall sizes of castings need not be toleranced.

Include all necessary notes and, if necessary, classes of fit. Use appendix tables for reference.

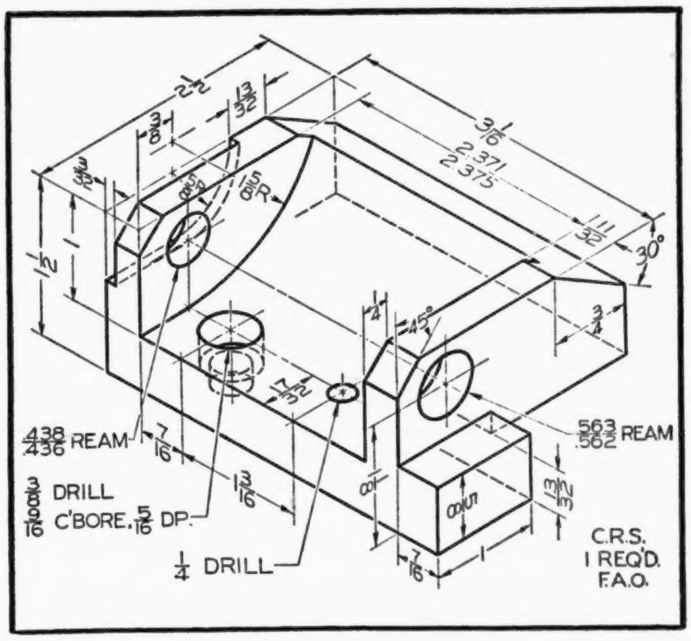
Keep in mind the tolerances for two and three place decimals given in your title block to determine the upper and lower limits for each dimension as you draw them. Maintain all tolerances already specified in the sketches as these are probably more critical than your tolerance requirements.

TERMINAL BLOCK

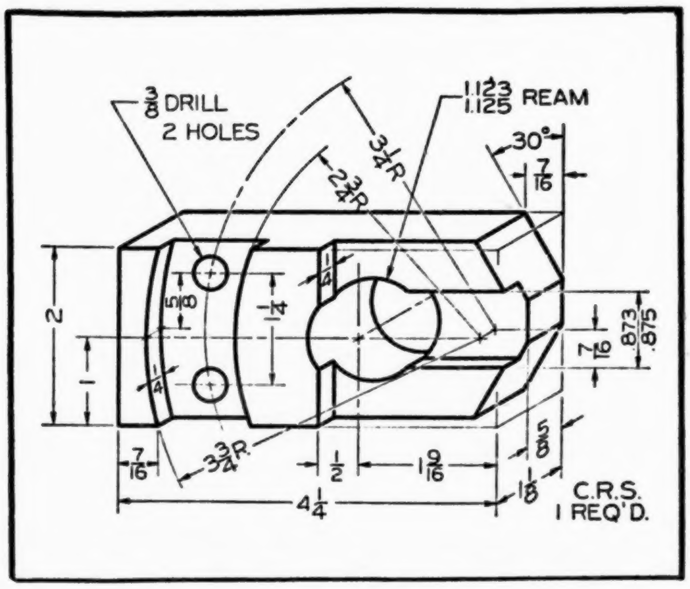

3/8 DRILL
1/2 C'BORE 9/16 DEEP
2 1/8
25/32
5/16
3/16
2 13/16
3/4 R
1 1/16 R
3/16
7/8
5/16
5/16
1/2 R
C.R.S.
1 REQ'D.
5 1/8
1 1/16
1 9/16

Problem 1.

HINGE PLATE

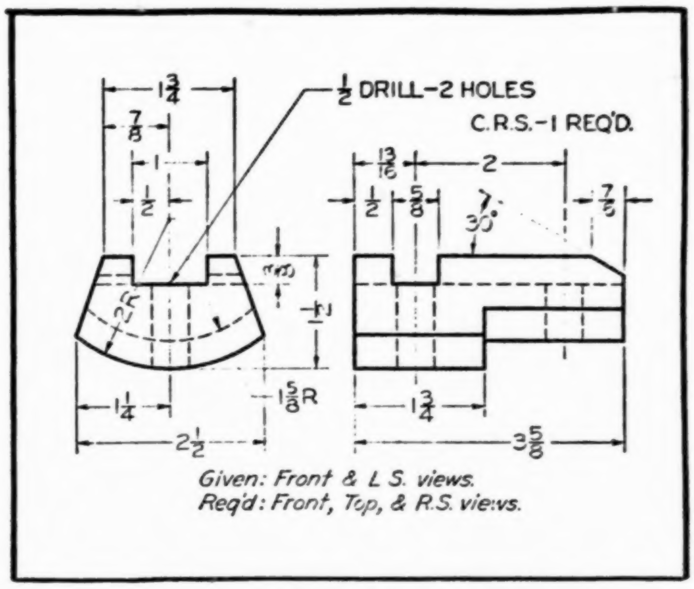

2 1/2
13/32
3/8
3 1/16
2.371
2.375
3/32
5/8 R
1 5/8 R
1 1/2
1
11/32
30°
1/4
45°
3/4
7/32
.438
.436 REAM
7/16
.563
.562 REAM
3/8 DRILL
9/16 C'BORE. 5/16 DP.
1 3/16
1/4 DRILL
5/8
3/8
1 3/32
7/16
1
C.R.S.
1 REQ'D.
F.A.O.

Problem 2.


3/8 DRILL 2 HOLES
1.123/1.125 REAM
30°
7/16
3 1/4 R
2 3/4 R
2
1
5/8
1 1/4
1/4
.873/.875
7/16
5/8
3 3/4 R
7/16
1/2
1 9/16
1 1/8
4 1/4
C.R.S.
1 REQ'D.

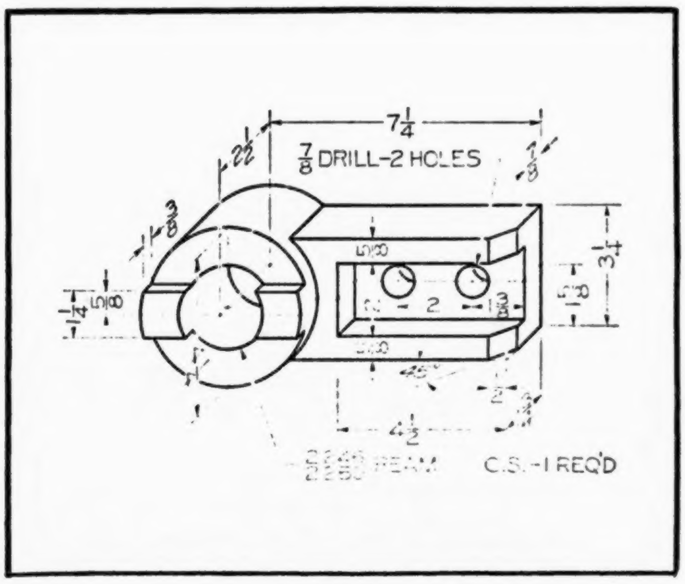
INDEX BASE

Problem 3.


1/2 DRILL-2 HOLES
C.R.S.-1 REQ'D.
1 3/4
7/8
1
1/2
13/16
2
1/2
5/8
7/8
30°
7/8
3/8
2 R
1 1/2
1 1/4
1 5/8 R
2 1/2
1 3/4
3 5/8
Given: Front & L.S. views.
Req'd: Front, Top, & R.S. views.

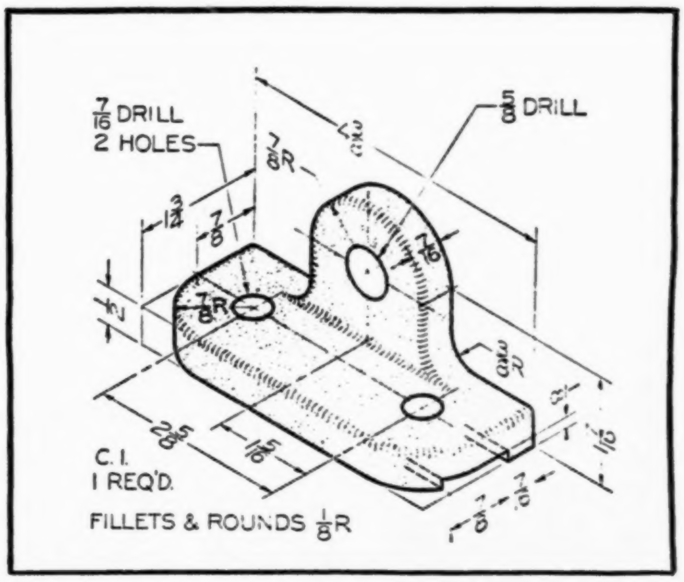
CAM BLOCK

Problem 4.


7 1/4
7/8 DRILL-2 HOLES
7/8
3/8
3 1/4
1 1/4
5/8
1 5/8
2
45°
4 1/2
C.S.-1 REQ'D

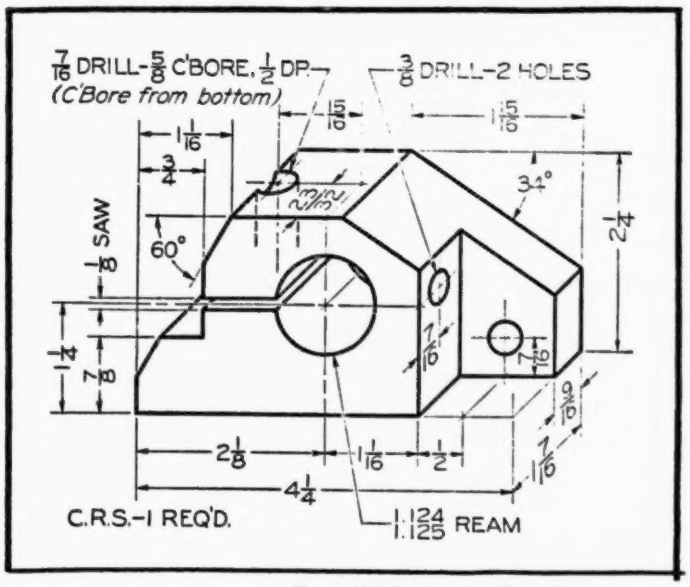
KEYED HUB PLATE

Problem 5.


7/16 DRILL
2 HOLES
5/8 DRILL
7/8 R
1 3/4
7/8
1/2
7/8 R
7/16
3/4 R
2 9/16
1 5/16
C.I.
1 REQ'D.
FILLETS & ROUNDS 1/8 R

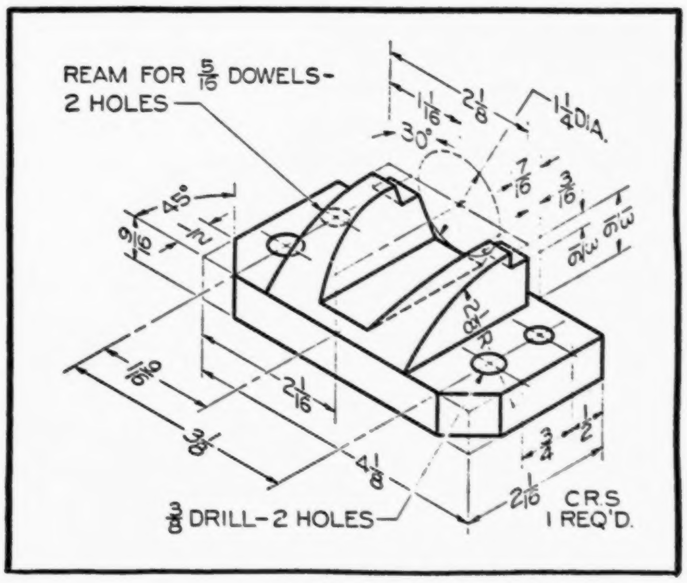
STOP BRACKET

Problem 6.


7/16 DRILL-5/8 C'BORE, 1/2 DP.
(C'Bore from bottom)
3/8 DRILL-2 HOLES
15/16
1 15/16
1 1/16
3/4
34°
1/8 SAW
60°
2 1/4
1 1/4
7/8
7/16
7/16
9/16
2 1/8
1 1/16
1/2
4 1/4
C.R.S.-1 REQ'D.
1.124/1.125 REAM

CLUTCH LEVER

Problem 7.


REAM FOR 5/16 DOWELS-
2 HOLES
1 1/16
2 1/8
1 1/4 DIA.
30°
45°
9/16
1/2
7/16
3/16
3/8
3/8
2 1/16
4 1/8
3/4
1/2
2 1/16
3/8 DRILL-2 HOLES
C.R.S
1 REQ'D.

LOCATING BLOCK

Problem 8.

UNIT IV - WORKING DRAWING INTERPRETATION

Threads and Fasteners

Lesson 4

OBJECTIVES:

1. To introduce methods of representing machine threads on working drawings.
2. To introduce drawing representation methods for basic thread forms.
3. To introduce methods of thread notation on working drawings.

REFERENCES:

1. Chapter 13, TECHNICAL DRAWING, Giesecke, Mitchell, and Spencer.
2. Chapter 12, MECHANICAL DRAWING, French and Svenson.

INFORMATION:

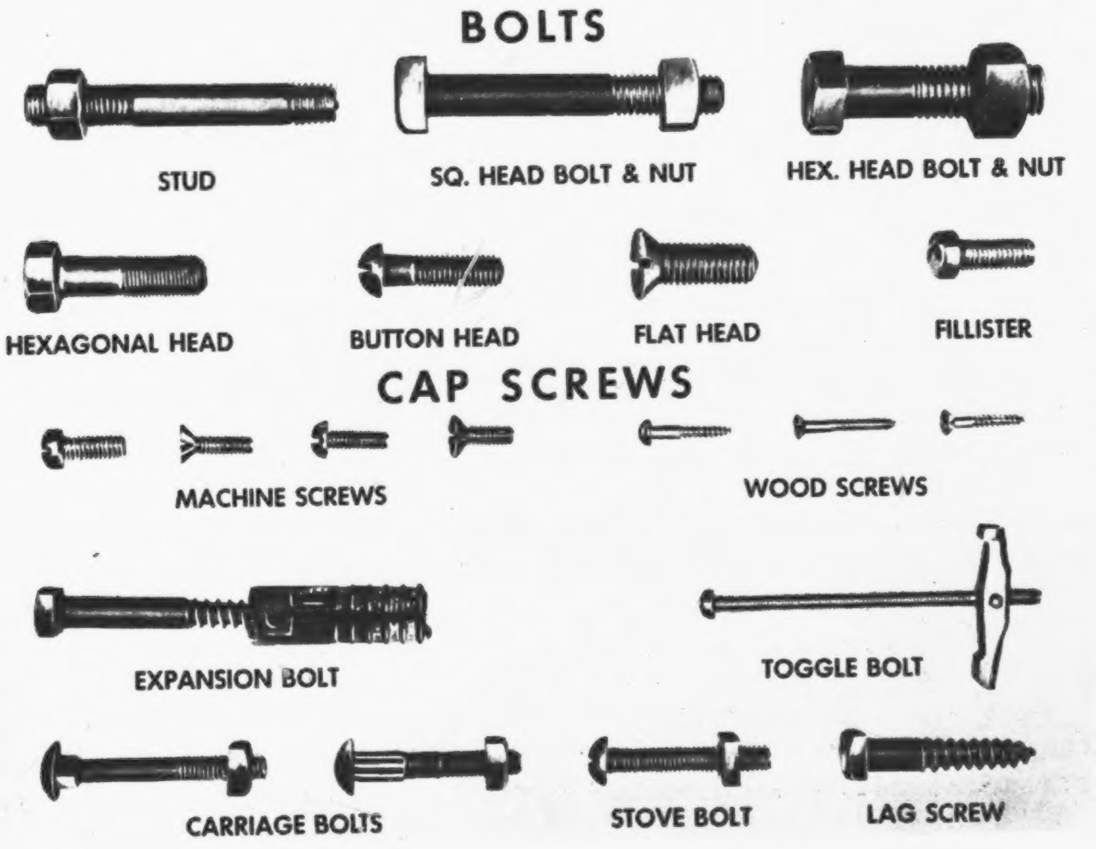
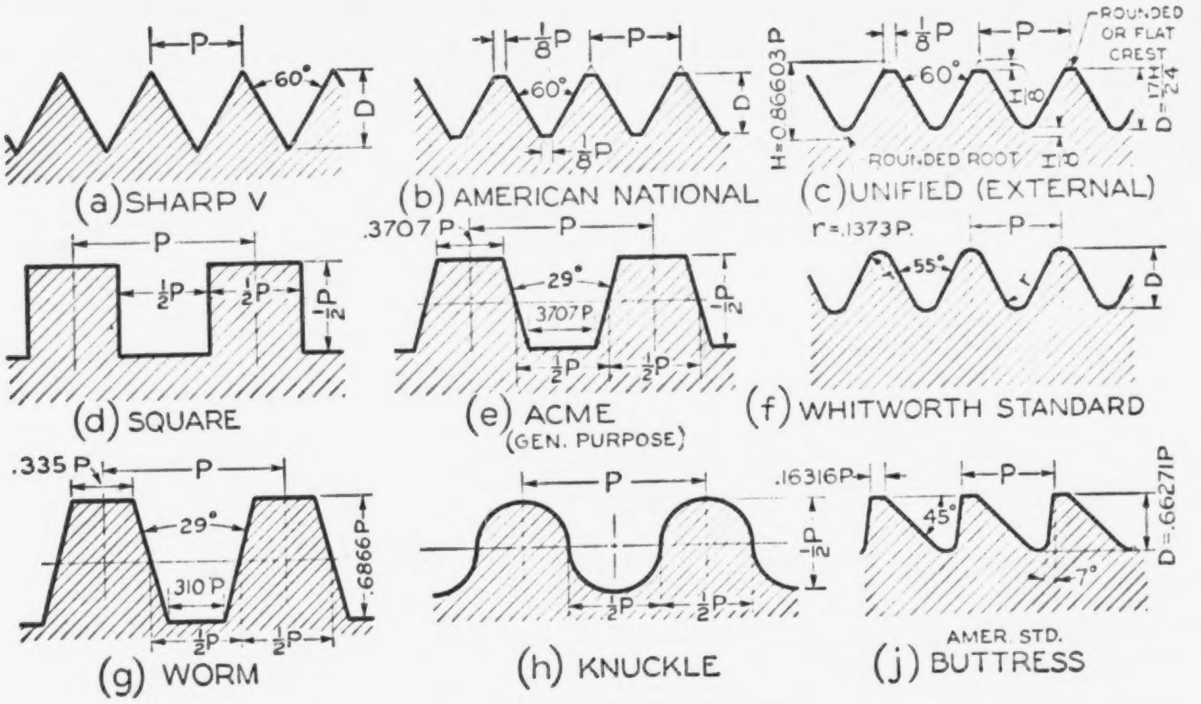

BOLTS
STUD
SQ. HEAD BOLT & NUT
HEX. HEAD BOLT & NUT
HEXAGONAL HEAD
BUTTON HEAD
FLAT HEAD
FILLISTER
CAP SCREWS
MACHINE SCREWS
WOOD SCREWS
EXPANSION BOLT
TOGGLE BOLT
CARRIAGE BOLTS
STOVE BOLT
LAG SCREW

Figure 1. Threaded Fasteners

Screw threads are used for three basic purposes:

to hold parts together
to adjust parts in reference to each other
to transmit power

The use of screw threads is so frequent (figure 1) that the common forms and methods of representation should be understood.


P
60°
D
(a) SHARP V
$\frac{1}{8}$P
P
60°
D
$\frac{1}{8}$P
(b) AMERICAN NATIONAL
H=0.86603 P
$\frac{1}{8}$P
P
ROUNDED OR FLAT CREST
60°
H/8
D=17H/24
ROUNDED ROOT
H/6
(c) UNIFIED (EXTERNAL)
P
$\frac{1}{2}$P
$\frac{1}{2}$P
$\frac{1}{2}$P
(d) SQUARE
.3707 P
P
29°
.3707 P
$\frac{1}{2}$P
$\frac{1}{2}$P
$\frac{1}{2}$P
(e) ACME (GEN. PURPOSE)
r=.1373P
P
55°
D
(f) WHITWORTH STANDARD
.335 P
P
29°
.310 P
.6866 P
$\frac{1}{2}$P
$\frac{1}{2}$P
(g) WORM
P
$\frac{1}{2}$P
$\frac{1}{2}$P
$\frac{1}{2}$P
(h) KNUCKLE
.16316P
P
45°
7°
D=.6627IP
AMER. STD.
(j) BUTTRESS

Screw-Thread Forms.

Figure 2.

Until standardization of the various thread "profiles" (figure 2) was accomplished, interchangeability of threaded parts from various manufacturers and other countries was impossible. Today, however, the American Standards Association provides specifications for threaded forms and sizes which are followed by manufacturers of threaded fasteners and related production machine tools.

Through coordination with Great Britain and Canada, the British and American thread forms have also been unified and have become a standard series.

Thread Series

Letter symbols provided in the American Standards are used to describe several SERIES of machine threads. Letter symbols include:

U unified
N National (American)
C coarse thread
S special thread
F fine thread
EF extra fine thread

Combinations of the letter symbols occur when a specific thread series is called for:

1. COARSE THREAD SERIES, UNC or NC. The pitch is relatively large for a specific diameter and is used for general engineering purposes.

2. FINE THREAD SERIES, UNF or NF. The pitch is smaller (greater number of threads per inch) for a specific diameter than for the coarse thread series. It is used where a finer thread is required as in automotive, aircraft, and similar industries.

3. EXTRA FINE THREAD SERIES, UNEF or NEF. The pitch is smaller than for the fine thread series. It is used where the depth of thread must be kept very small as on aircraft equipment, thin-walled tubes, and so forth.

Three series provide for the same number of threads per inch regardless of the diameter:

1. 8-THREAD SERIES, 8N. This series uses 8 threads per inch for all diameters.

2. 12-THREAD SERIES, 12N. This series uses 12 threads per inch for all diameters.

3. 16-THREAD SERIES, 16N. This series uses 16 threads per inch for all diameters.

4. SPECIAL THREADS, UN, UNS, or NS. These are nonstandard or special combinations of diameter, pitch, and length of engagement.

Thread Notes

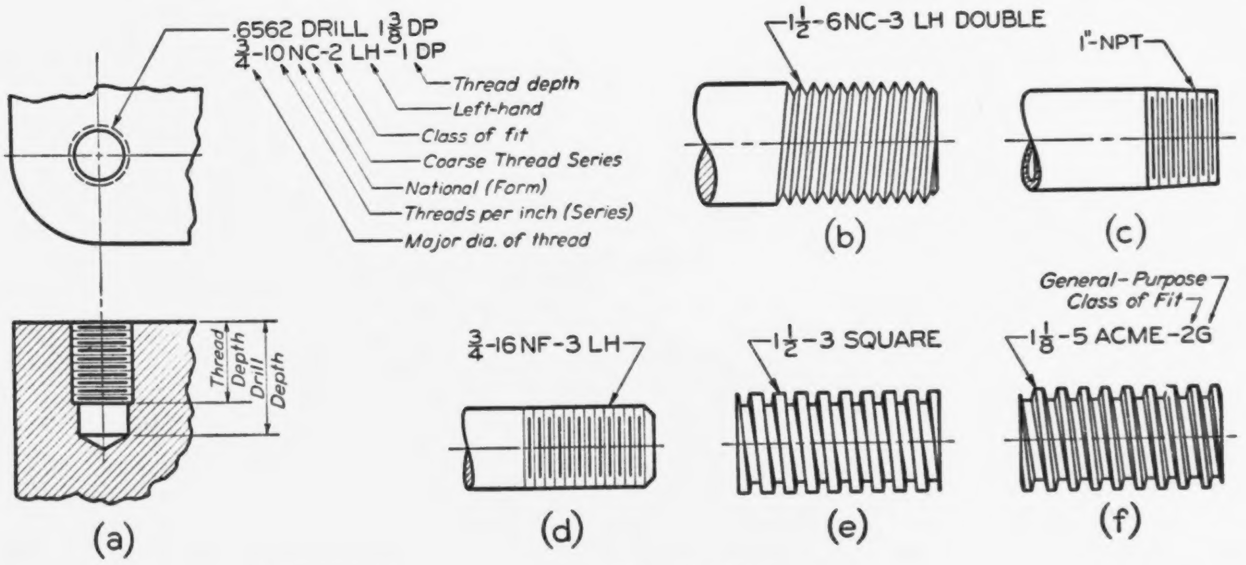
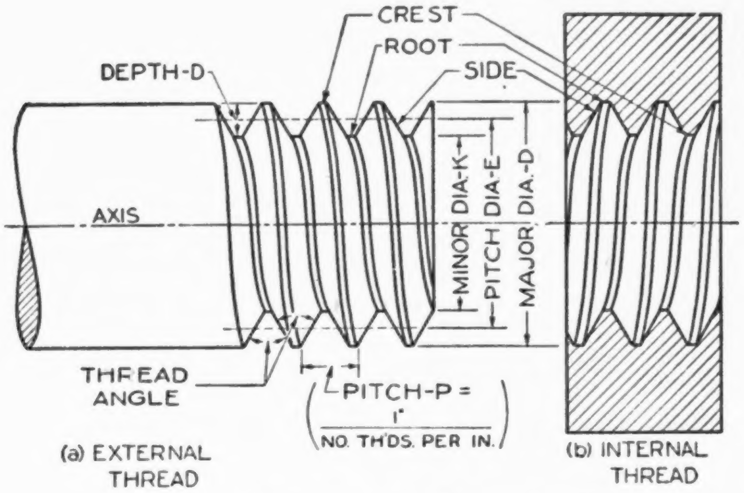

.6562 DRILL 1 3/8 DP
3/4-10 NC-2 LH-1 DP
Thread depth
Left-hand
Class of fit
Coarse Thread Series
National (Form)
Threads per inch (Series)
Major dia. of thread
Thread Depth
Drill Depth
(a)
1 1/2-6NC-3 LH DOUBLE
(b)
1"-NPT
(c)
3/4-16NF-3 LH
(d)
1 1/2-3 SQUARE
(e)
General-Purpose Class of Fit
1 1/8-5 ACME-2G
(f)

Figure 3. **Thread Notes.**

In addition to the specification of a particular series of thread on your drawings, the diameter, pitch, class of fit, direction of rotation, and depth should also be included as part of your notes.

Before proceeding further, it is necessary to define some common thread terms to provide understanding of threads in connection with the required notations on your drawings.



Screw-Thread Nomenclature.

Figure 4.

SCREW THREAD - A ridge of uniform section in the form of a helix on the external or internal surface of a cylinder.

EXTERNAL THREAD - A thread on the outside of a member.

INTERNAL THREAD - A thread on the inside of a member.

MAJOR DIAMETER - The largest diameter of a screw thread (applies to both internal and external threads).

MINOR DIAMETER - The smallest diameter of a screw thread (applies to both internal and external threads).

PITCH - The distance from a point on a screw thread to a corresponding point on the next thread measured parallel to the axis. The pitch is equal to one inch divided by the number of threads per inch.

PITCH DIAMETER - The diameter of an imaginary cylinder passing through the threads so as to make equal the widths of the threads and the widths of the spaces cut by the cylinder.

LEAD - The distance a screw thread advances axially in one turn.

ANGLE OF THREAD - The angle included between the sides of the thread measured in a plane through the axis of the screw (figure 4).

CREST - The top surface joining the two sides of a thread.

ROOT - The bottom surface joining the sides of two adjacent threads.

SLIDE - The surface of the thread which connects the crest with the root.

AXIS OF SCREW - The longitudinal center line through the screw.

DEPTH OF THREAD - The distance between the crest and the root of the thread measured normal to the axis.

FORM OF THREAD - The cross section of thread cut by a plane containing the axis.

SERIES OF THREAD - Standard number of threads per inch for various diameters.

You will notice that all information given in a note is abbreviated as much as possible (figure 3). Notice also that a direct relationship is made to the machining processes necessary to produce both the hole and thread. Use of complete notes is recommended since drill depths and special tap requirements often become confusing (figure 3a). As a student, especially, do not take for granted that your drawings will be understood unless the notes are complete.

Note. When a hole is drilled through an object, the abbreviation THRU replaces the word "deep" (DP.).

The representation of various thread forms is shown in figure 2. Observe particularly that the notations are written horizontally and are given in the longitudinal view of the thread. Lead lines in this case contact the edges of the threaded object anywhere along its length. Remember the lead lines are never drawn vertically or horizontally on the page.

Direction of Rotation

The terms "right hand" and "left hand" relate the direction in which a thread is revolved to advance it. For example (figure 5), a right-hand (RH) threaded bolt will advance into the nut when revolved clockwise. The reverse direction of rotation applies to left-hand (LH) threads. A thread on a drawing is always understood to be right hand if no note is given. A left-hand thread is always marked (LH) on a drawing. No note is given for a RH thread.

Notice in figure 5a-b the direction of "slope" on the thread representations. The slope representation of an exposed internal thread must directly oppose that of an external thread since in actuality you are showing the opposite half of the thread. In other words, the back portion of the external thread slope matches the internal slope.

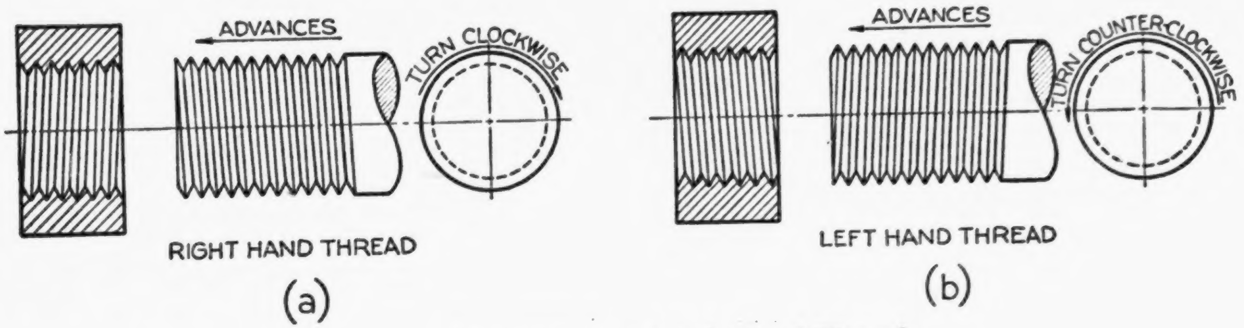


Figure 5. **Right-Hand and Left-Hand Threads.**

Class of Fit

The tolerances to which fit between external and internal threads are held fall into four categories specified by the American Standards. The draftsman should specify this requirement with thread notations (figure 3a). For available classes of fit with various thread forms, see appendix tables.

CLASS 1 FIT- recommended only for screw thread work where clearance between mating parts is essential for rapid assembly and where shake or play is not objectionable.

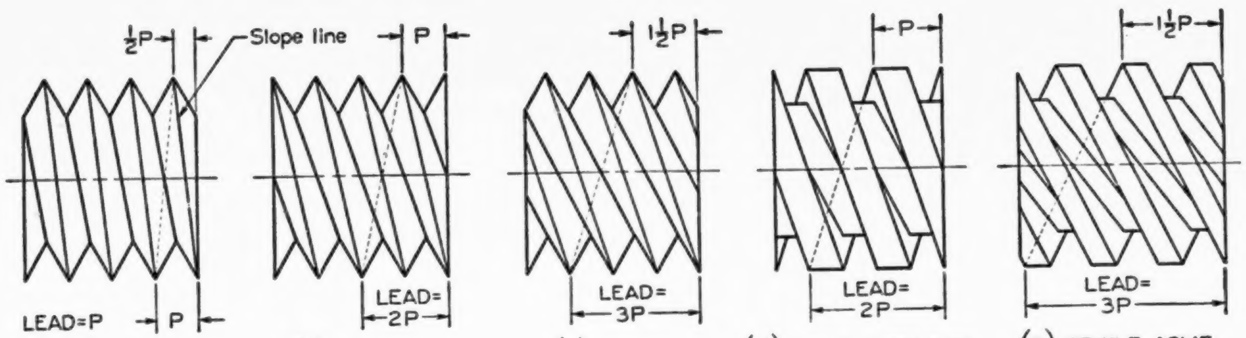
CLASS 2 FIT- represents a high quality of commercial thread product and is recommended for the great bulk of interchangeable screw thread work.

CLASS 3 FIT- represents an exceptionally high quality of commercially threaded products and is recommended only in cases where the high cost of precision tools and continual checking are warranted.

CLASS 4 FIT- intended to meet very unusual requirements more exacting than those for which Class 3 is intended. It is a selective fit if initial assembly by hand is required. It is not as yet adaptable to quantity production.

Note. The Unified Series of thread differs in notation from American National Threads by the addition of the letter "U" before the series letter, and by the addition of the letters "A" or "B" following the class of fit. "A" is used to indicate "external thread", and "B", an "internal thread."

Multiple Threads



(a) SINGLE (b) DOUBLE (c) TRIPLE (d) DOUBLE SQUARE (e) TRIPLE ACME

Figure 6. **Multiple Threads.**

The common SINGLE thread is composed of a single "ridge" or thread crest running the length of the thread (figure 6a).

MULTIPLE threads are composed of two or more ridges running side by side (figure 6b-c). The "slope" of the single thread is offset on one side a distance to one-half of the pitch (P). For double threads, a distance equal to (P); and for triple threads, a distance equal to 1½ P.

On a detailed drawing of a single thread or a triple thread, a crest is opposite a root; for double threads or quadruple threads, a root is opposite a root.

In one turn, a double thread advances twice as far as a single thread (distance = to 2P), and a triple thread three times as far (3P), and so on.

Multiple threads find application wherever quick motion is desired in place of great power. Some common uses are pen parts, toothpaste caps, valve stems, etc. Multiple threads can be counted by observing the number of thread endings on the screw.

Representation of Threads on Drawings

The American Standard thread is basically a 60° "V" form of thread, except that "flats" are included on the crest in manufacture (figure 7). These flats are disregarded when representing the threads on the drawing.

Since the 60° "V" form of thread is the most commonly used, this method of construction will be discussed.

Note. FOR CONSTRUCTION OF OTHER THREAD FORMS, as square, acme, worm, buttress, etc., USE REFERENCE TEXTS RECOMMENDED AT BEGINNING OF LESSON or other drawing texts supplying the required information.

Both American National and Unified Threads are represented in the same manner in drawing.

Detailing "V" Threads

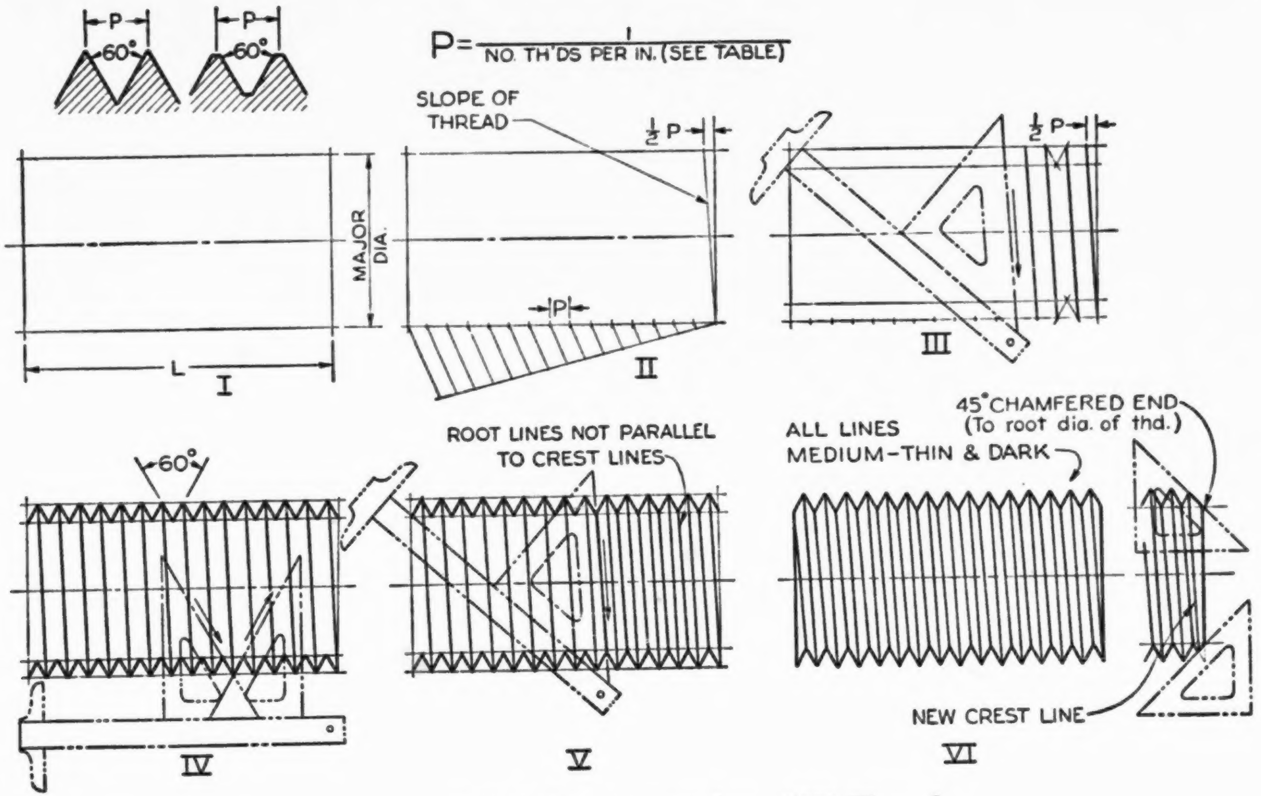

P
60°
P
60°
P = 1 / NO. TH'DS PER IN. (SEE TABLE)
SLOPE OF THREAD
½ P
MAJOR DIA.
L
I
P
II
½ P
III
60°
ROOT LINES NOT PARALLEL TO CREST LINES
ALL LINES MEDIUM-THIN & DARK
45° CHAMFERED END (To root dia. of thd.)
NEW CREST LINE
IV
V
VI

Figure 7. Detailed Representation—"V" Threads.

Before representing a thread on a drawing, regardless of the method used, you must first possess certain information:

1. diameter of the thread
2. pitch of the thread (P) (1 divided by # of T/in.)
3. root diameter or tap drill size
4. length of the thread
5. lead (single, double, triple, etc.)
6. direction of rotation (LH or RH).

Having gathered the above information, follow step by step the following process for drawing a 60° V-form thread. Numerals at the beginning of each statement refer to the illustrated steps in figure 7.

I. Draw a center line; lay out length and major diameter.

II. Establish "slope" by offsetting proper distance. Offset at top of view for RH thread and at bottom for LH threads (for right-hand external threads, ILLUSTRATED lines slope upward to the left). Set off the pitch point with the scale or dividers.

Note. FOR THREADS WHICH CANNOT BE SET OFF USING THE SCALE DIRECTLY, USE THE PARALLEL LINE METHOD.

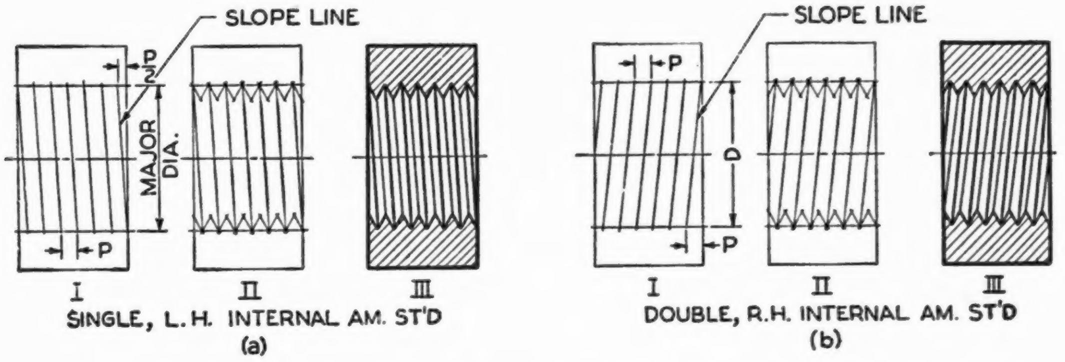
III. From pitch points, draw lines parallel to the slope line. OFFSET INSTRUCTIONS AS REQUIRED. Draw two V's to establish depth of thread, and draw guide lines for root of thread.

IV. Draw 60° V's finished line weight. These V's should stand vertically. They are not slanted with the thread.

V. Align instruments and draw finished line connecting the roots of the threads. Align instruments and connect crests of the threads. ROOT AND CREST LINES ARE NOT PARALLEL TO ONE ANOTHER.

VI. All lines are the same weight. When the end of the thread is chamfered (usually 45°, sometimes 30°), the chamfer extends to the depth of the thread.

Figure 8.



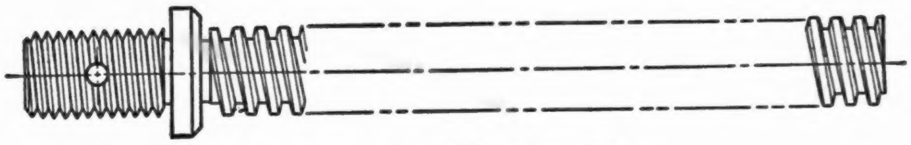
I II III
SINGLE, L.H. INTERNAL AM. ST'D
(a)

I II III
DOUBLE, R.H. INTERNAL AM. ST'D
(b)

Semi-Conventional Sharp-V, or American Standard Threads (Internal).

Internal threads are detailed by the same procedure (figure 8). Remember that the slope is reversed for internal threads.

For extended thread representation on detail drawing, not all threads need be drawn. Figure 9 shows how phantom lines may be used to reduce the amount of work involved. In this case, a few threads are represented on either end of the threaded portion to give desired details, the remaining area being connected by phantom lines.



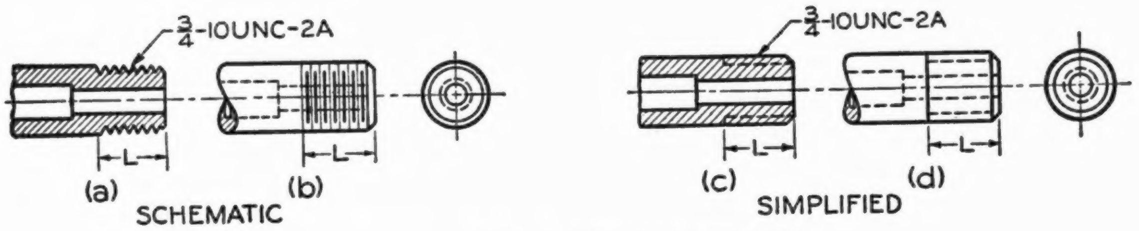
Use of Phantom Lines.

Figure 9.

Thread Symbols

The described manner of representing threads is known as the "semi-conventional" method. "Conventional" thread representation (figure 4) involves the drawing of the thread helices (curves of the thread). This presents a pleasing appearance, but the task of plotting the helices is too time-consuming to be practical in the drawing room. In fact, the "semi-conventional" method is being rapidly replaced by the use of the American Standard symbols which compose the "schematic" and "simplified" methods of thread representation (figures 10-12).

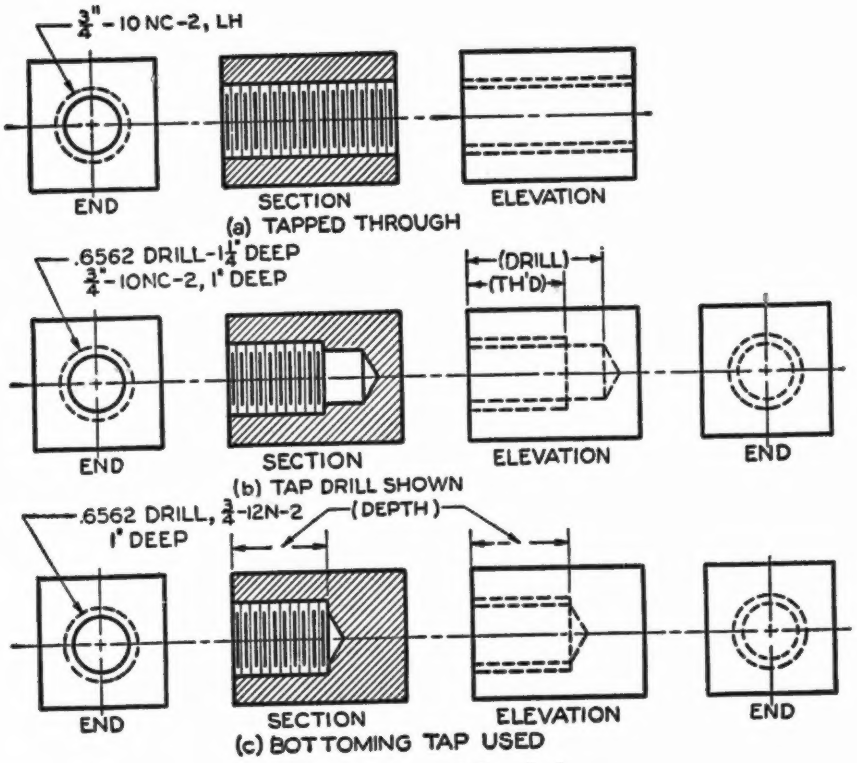
The illustration of the thread symbols include notation forms in their related positions on the various views.



$\frac{3}{4}$-10UNC-2A
L
(a)
(b)
SCHEMATIC
$\frac{3}{4}$-10UNC-2A
L
(c)
(d)
SIMPLIFIED

External Thread Symbols.

Figure 10.



$\frac{3}{4}$"-10 NC-2, LH
END
SECTION
ELEVATION
(a) TAPPED THROUGH
.6562 DRILL-1$\frac{1}{4}$" DEEP
$\frac{3}{4}$"-10NC-2, 1" DEEP
(DRILL)
(TH'D)
END
SECTION
ELEVATION
END
(b) TAP DRILL SHOWN
.6562 DRILL, $\frac{3}{4}$-12N-2
1" DEEP
(DEPTH)
END
SECTION
ELEVATION
END
(c) BOTTOMING TAP USED

Figure 11.

Internal Thread Symbols —

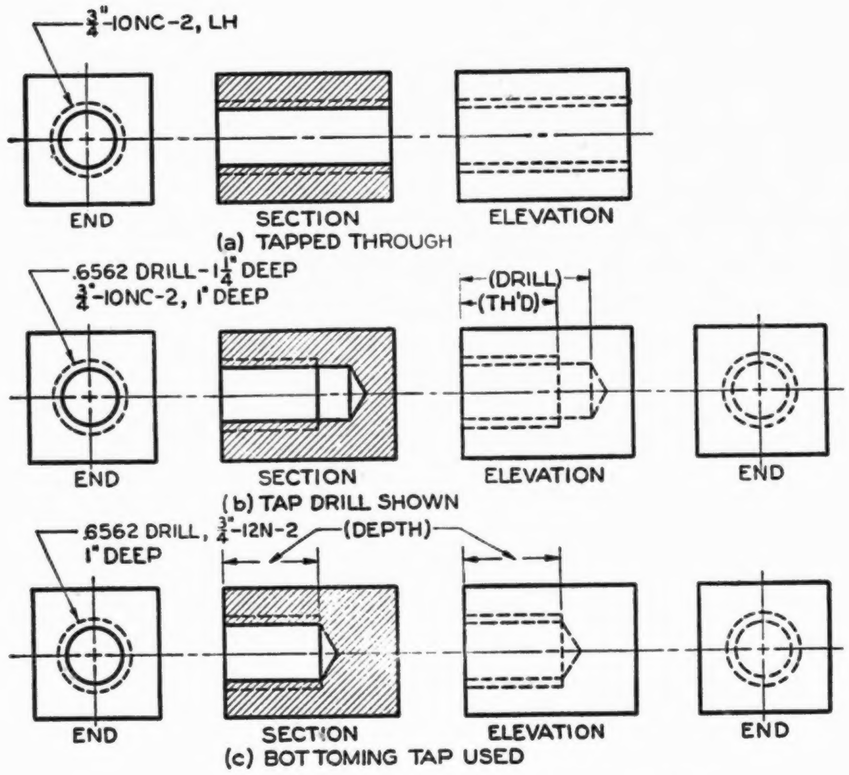

3/4"-10NC-2, LH
END
SECTION
ELEVATION
(a) TAPPED THROUGH
.6562 DRILL-1 1/4" DEEP
3/4"-10NC-2, 1" DEEP
(DRILL)
(TH'D)
END
SECTION
ELEVATION
END
(b) TAP DRILL SHOWN
.6562 DRILL, 1" DEEP
3/4"-12N-2
(DEPTH)
END
SECTION
ELEVATION
END
(c) BOTTOMING TAP USED

Figure 12.

Internal Thread Symbols — Simplified.

Drawing Schematic Thread Symbols

The thread symbols are applied to the drawing of all threads under one inch in diameter. The same symbols are used for all common thread forms. The type of thread is simply indicated by the thread notation.

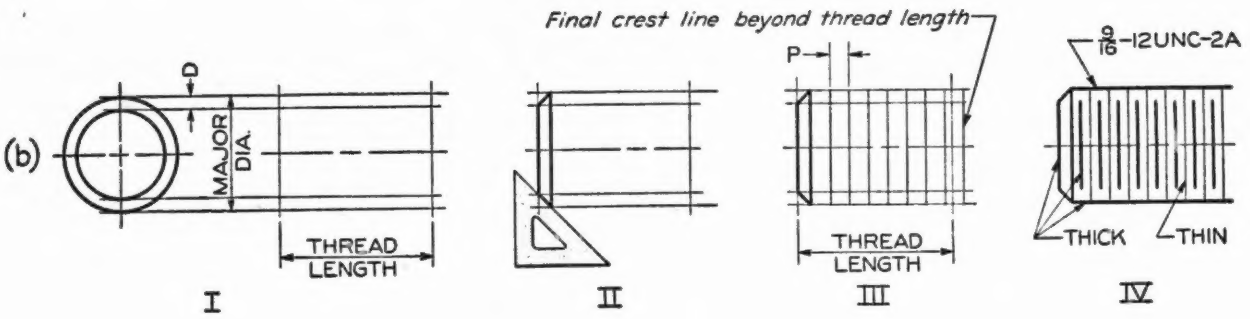
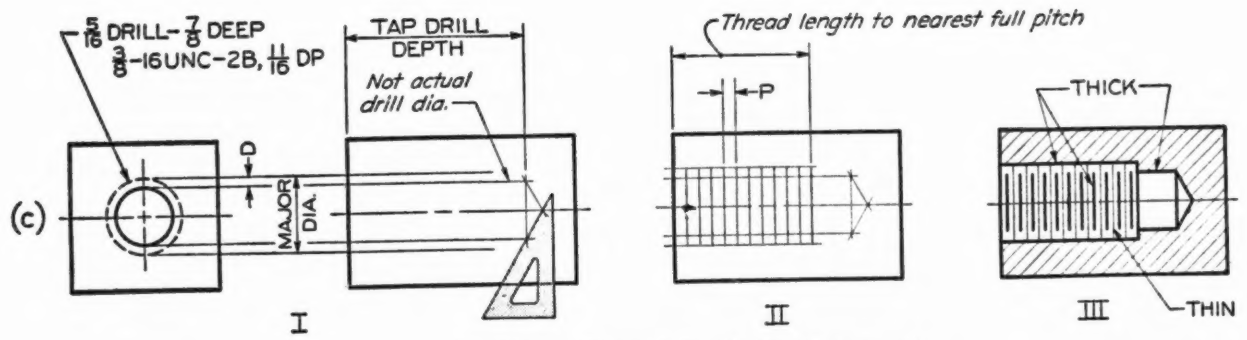

Final crest line beyond thread length
P
9/16-12UNC-2A
D
MAJOR DIA.
(b)
THREAD LENGTH
THREAD LENGTH
THICK
THIN
I
II
III
IV

Figure 13.


5/16 DRILL-7/8 DEEP
3/8-16UNC-2B, 11/16 DP
TAP DRILL DEPTH
Not actual drill dia.
D
MAJOR DIA.
(c)
Thread length to nearest full pitch
P
THICK
THIN
I
II
III

To Draw Thread Symbols—Schematic.

Figure 14.

In drawing the schematic thread symbols, alternate THICK and THIN lines are used to represent the threads.

Follow the illustrated steps for drawing.

Thin lines are used to set off the pitch, and thick lines are used to represent the root diameter. Lines are spaced using the scale. Major and minor diameters are also established using the scale. Note that the thread length is represented to the nearest full pitch and that the thread representative ends with a crest line. Threads are chamfered to the root diameters.

> Note. For INTERNAL THREADS, THE DRILLED HOLE EXTENDS BEYOND THE TAPPED (or threaded length) AREA FOR A DISTANCE OF THREE PITCHES OR GREATER. A regular tap in machine work cannot produce effective threads to the bottom of a hole. Full depth threads are produced by a "bottoming tap", and the operation must be noted on the drawing.

Fastening Systems

There are many types of fastening devices available which employ the American Standard screw threads. The appendix tables included with this study of drawing describe the proportion for the common types of American Standard fasteners as cap screws, machine screws, square and hexagon bolts and nuts.

Standard fasteners are manufactured from stock material forms and are generally called for on detail drawings by a note specifying type, size, thread form, etc.

Only in cases where special types or sizes of fasteners are called for are detail drawings made.

There are, however, times when screws or bolts may have to be shown on drawings, particularly on assembly drawings. The thread representations outlined apply to all detail and assembly drawings of fasteners.

USE REFERENCE TEXTS which describe drawing methods and proportions for square and hexagonal bolts or machine screw forms as they are required on your drawings.

QUESTIONS:

1. What type of multiple thread is found on your ball-point pen parts? Why?
2. What is the included angle of the standard "V" thread?
3. What is meant by the slope of a thread?
4. Where may phantom lines be substituted for thread details?
5. Where do differences occur between the schematic and simplified representations of internal threads?
6. Why is the tap drill diameter smaller than the desired thread size?
7. What is a bottoming tap? Why is it more costly to produce this type of thread?
8. How many turns would be required to advance a double thread of $\frac{1}{8}$", pitch $1\frac{1}{2}$"? In what direction of rotation?
9. On a unified thread notation, what do the symbols "2B" mean at the end of the note?
10. List three machines which depend on the principle of screw threads for their operation.

ASSIGNMENT:

The following exercises are designed to develop accuracy both in the use of instruments and in the representation of threads through the application of standard symbols.

Problem 1. Divide a size A sheet and place horizontally into four working areas. Use the simplified title block. In each of the spaces do one of the following exercises representing threads by the detailed V-form. See appendix table - American Standard Machine Screws - for construction detail of required heads and slot sizes.

A Round Head - 1" - 8 N.C.

B Flat Head - $\frac{3}{4}$" - 10 N.C.

C Fillister Head - $\frac{1}{2}$" - 12 N.C.

D Oval Head - $\frac{3}{8}$" - 16 N.C.

The thread length in each case will be two times the diameter plus one-quarter inch, allowing a distance equal to the diameter as the difference between total length and thread length. All work--full scale. All exercises are one-view drawings placed horizontally within the working area. Title the entire plate: American Standard Machine Screws.

Problem 2. Use size A paper with the simplified title block form. Divide the sheet into four equal working areas with border lines. In each space a one-view drawing representing a threaded shaft will be made.

1) In the two top spaces, using schematic thread symbols, draw a rectangular area representing the threaded shaft for each of the following:

1" - 8 N.C. 3 " long

$\frac{3}{4}$" - 12 N.C. $2\frac{1}{2}$" long

Chamfer the right end at 45° according to the methods outlined.

2) Using the simplified thread symbols, draw the following representations in the two lower areas:

$\frac{1}{2}$" - 12 N.C. 2" long

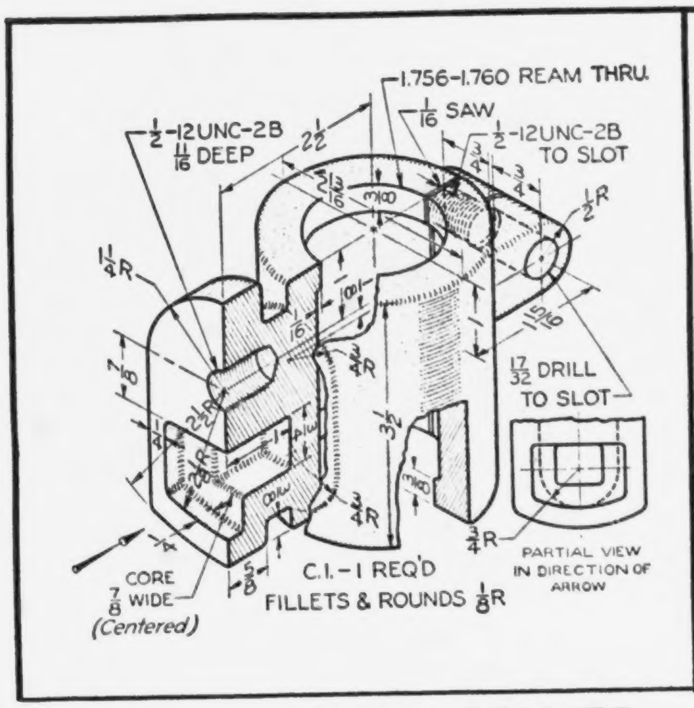
$\frac{3}{8}$" - 16 N.C. 2" long

Chamfer the right end at 30° using the prescribed methods.

Problems 3 - 6.

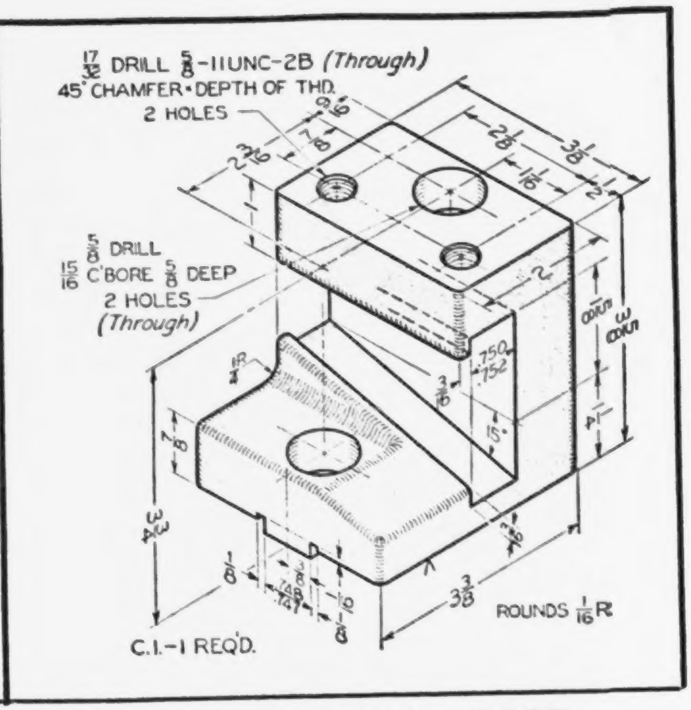
Draw the required details for problems 3 - 6 using size B paper with the working drawing title block form. Include all required thread representations and notes drawn in the prescribed manner.

Note. USE PARTIAL VIEWS WHERE POSSIBLE.


1.756-1.760 REAM THRU.
1/16 SAW
1/2-12UNC-2B TO SLOT
1/2-12UNC-2B 11/16 DEEP
1 1/4 R
17/32 DRILL TO SLOT
PARTIAL VIEW IN DIRECTION OF ARROW
CORE 7/8 WIDE (Centered)
C.I.-1 REQ'D
FILLETS & ROUNDS 1/8R

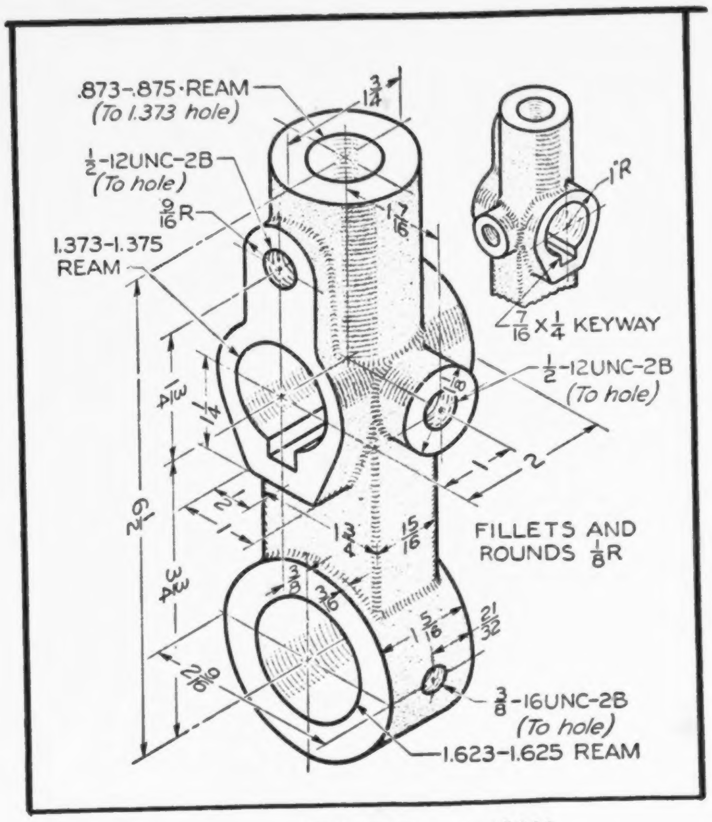
COLUMN BRACKET

Problem 3.


17/32 DRILL 5/8-11UNC-2B (Through)
45° CHAMFER = DEPTH OF THD.
2 HOLES
5/8 DRILL
15/16 C'BORE 5/8 DEEP
2 HOLES (Through)
.750 .752
15°
C.I.-1 REQ'D.
ROUNDS 1/16 R

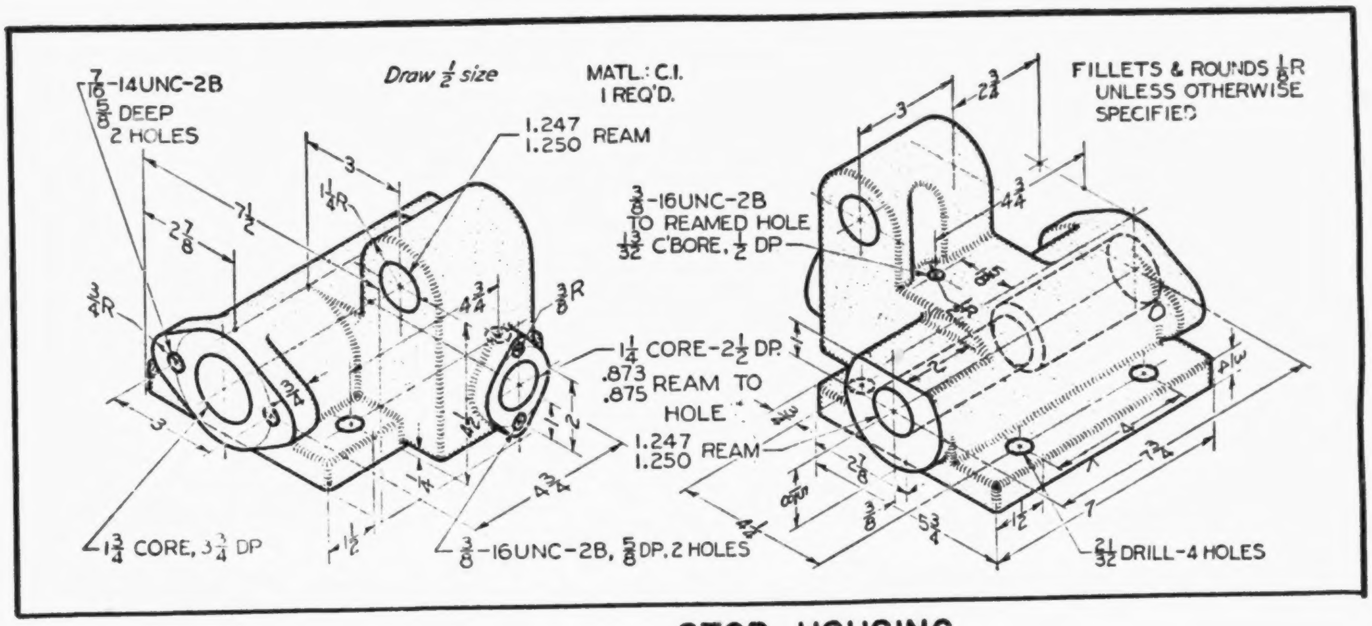
R.H. TOOL POST

Problem 4.


.873-.875 REAM (To 1.373 hole)
1/2-12UNC-2B (To hole)
9/16 R
1.373-1.375 REAM
1" R
7/16 X 1/4 KEYWAY
1/2-12UNC-2B (To hole)
FILLETS AND ROUNDS 1/8 R
3/8-16UNC-2B (To hole)
1.623-1.625 REAM

IDLER LINK

Problem 5.



Draw $\frac{1}{2}$ size

MATL.: C.I.
1 REQ'D.

FILLETS & ROUNDS $\frac{1}{8}$R
UNLESS OTHERWISE
SPECIFIED

$\frac{7}{16}$-14UNC-2B
$\frac{5}{8}$ DEEP
2 HOLES
1.247 / 1.250 REAM
3
$7\frac{1}{2}$
$1\frac{1}{4}$R
$2\frac{7}{8}$
$\frac{3}{4}$R
$4\frac{3}{4}$
$\frac{3}{8}$R
$\frac{3}{4}$
3
$1\frac{3}{4}$ CORE, $3\frac{3}{4}$ DP
$1\frac{1}{2}$
$\frac{1}{4}$
$\frac{1}{2}$
2
$4\frac{3}{4}$
$\frac{3}{8}$-16UNC-2B, $\frac{5}{8}$DP. 2 HOLES
$1\frac{1}{4}$ CORE-$2\frac{1}{2}$ DP.
.873 / .875 REAM TO HOLE
1.247 / 1.250 REAM
$\frac{3}{8}$-16UNC-2B
TO REAMED HOLE
$1\frac{3}{32}$ C'BORE, $\frac{1}{2}$ DP
3
$2\frac{3}{4}$
$4\frac{3}{4}$
$\frac{5}{16}$
2
$\frac{3}{4}$
$\frac{5}{8}$
$2\frac{7}{8}$
$\frac{3}{8}$
$5\frac{3}{4}$
$4\frac{1}{4}$
$\frac{1}{2}$
7
$7\frac{3}{4}$
4
$\frac{3}{4}$
$\frac{21}{32}$ DRILL-4 HOLES

STOP HOUSING

Problem 6.

UNIT IV - WORKING DRAWING INTERPRETATION

Working Drawing Review   Lesson 5

OBJECTIVES:

1. To review the purpose of working drawings.
2. To relate design objectives.
3. To review proper drawing content and layout.

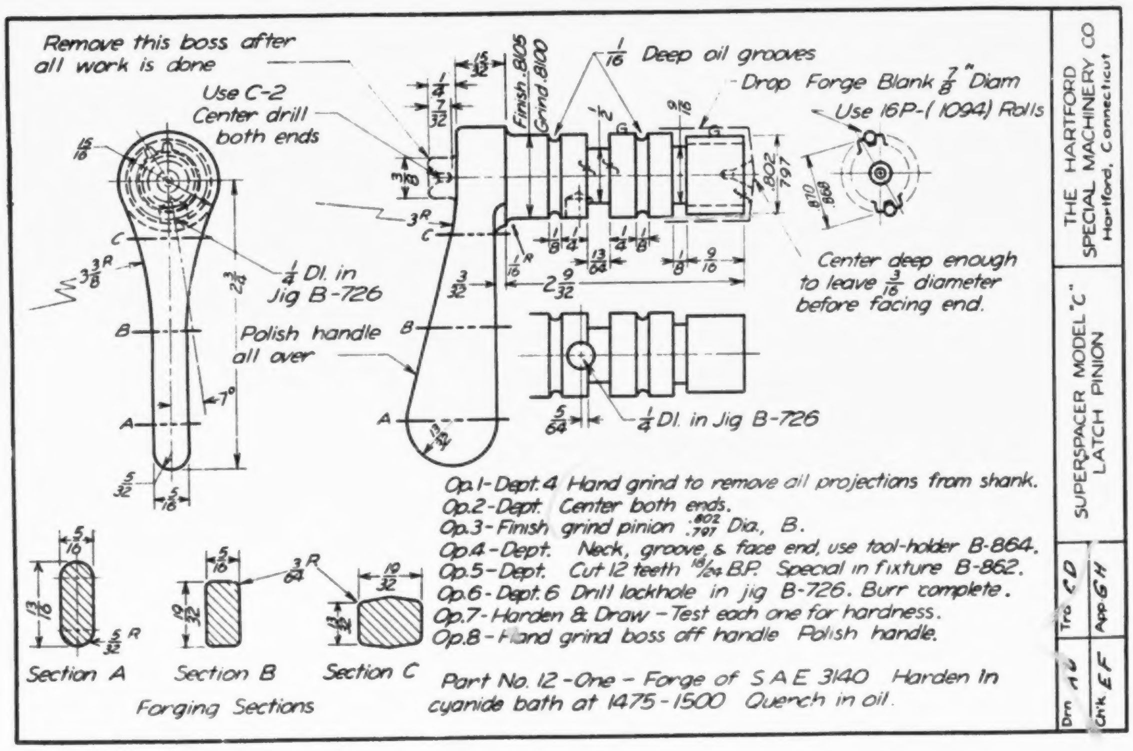
REFERENCES:

1. Chapter 14, TECHNICAL DRAWING, Giesecke, Mitchell, and Spencer.
2. Chapter 13, MECHANICAL DRAWING, French.

INFORMATION:

A good working drawing is based upon the proper application of the procedures outlined in the several past lessons. Working drawings are based upon orthographic projection,and include all dimensions and notes necessary to adequately describe the part in question. Good drawing practice is of utmost importance. Proper contrast of line weights, easy-to-read figures, uniform lettering, and the use of standard terms are essential to useful working drawings.

Detail Drawings



Remove this boss after all work is done
Use C-2 Center drill both ends
$\frac{15}{16}$
$3\frac{3}{8}$R
C
B
A
$2\frac{3}{4}$
$\frac{1}{4}$ Dl. in Jig B-726
Polish handle all over
7°
$\frac{5}{32}$
$\frac{5}{16}$
$\frac{15}{32}$
$\frac{1}{4}$
$\frac{7}{32}$
Finish .8105
Grind .8100
$\frac{1}{16}$ Deep oil grooves
Drop Forge Blank $\frac{7}{8}$" Diam
Use 16P-(1094) Rolls
$\frac{3}{16}$
3R
$\frac{1}{16}$R
$\frac{3}{32}$
$\frac{1}{8}$
$\frac{13}{64}$
$\frac{9}{16}$
$2\frac{9}{32}$
G
.802
.797
.870
.868
Center deep enough to leave $\frac{3}{16}$ diameter before facing end.
$\frac{13}{32}$
$\frac{5}{64}$
$\frac{1}{4}$ Dl. in Jig B-726
$\frac{13}{16}$
$\frac{5}{32}$R
$\frac{19}{32}$
$\frac{3}{64}$R
$\frac{10}{32}$
Section A
Section B
Section C
Forging Sections
Op.1-Dept.4 Hand grind to remove all projections from shank.
Op.2-Dept. Center both ends.
Op.3-Finish grind pinion $\frac{.802}{.797}$ Dia., B.
Op.4-Dept. Neck, groove, & face end, use tool-holder B-864.
Op.5-Dept. Cut 12 teeth $\frac{16}{24}$ B.P. Special in fixture B-862.
Op.6-Dept.6 Drill lockhole in jig B-726. Burr complete.
Op.7-Harden & Draw - Test each one for hardness.
Op.8-Hand grind boss off handle Polish handle.
Part No. 12-One - Forge of S A E 3140 Harden in cyanide bath at 1475-1500 Quench in oil.
THE HARTFORD SPECIAL MACHINERY CO
Hartford, Connecticut
SUPERSPACER MODEL "C" LATCH PINION
Drn AB
Tra CD
Chk EF
App GH

Figure 1.

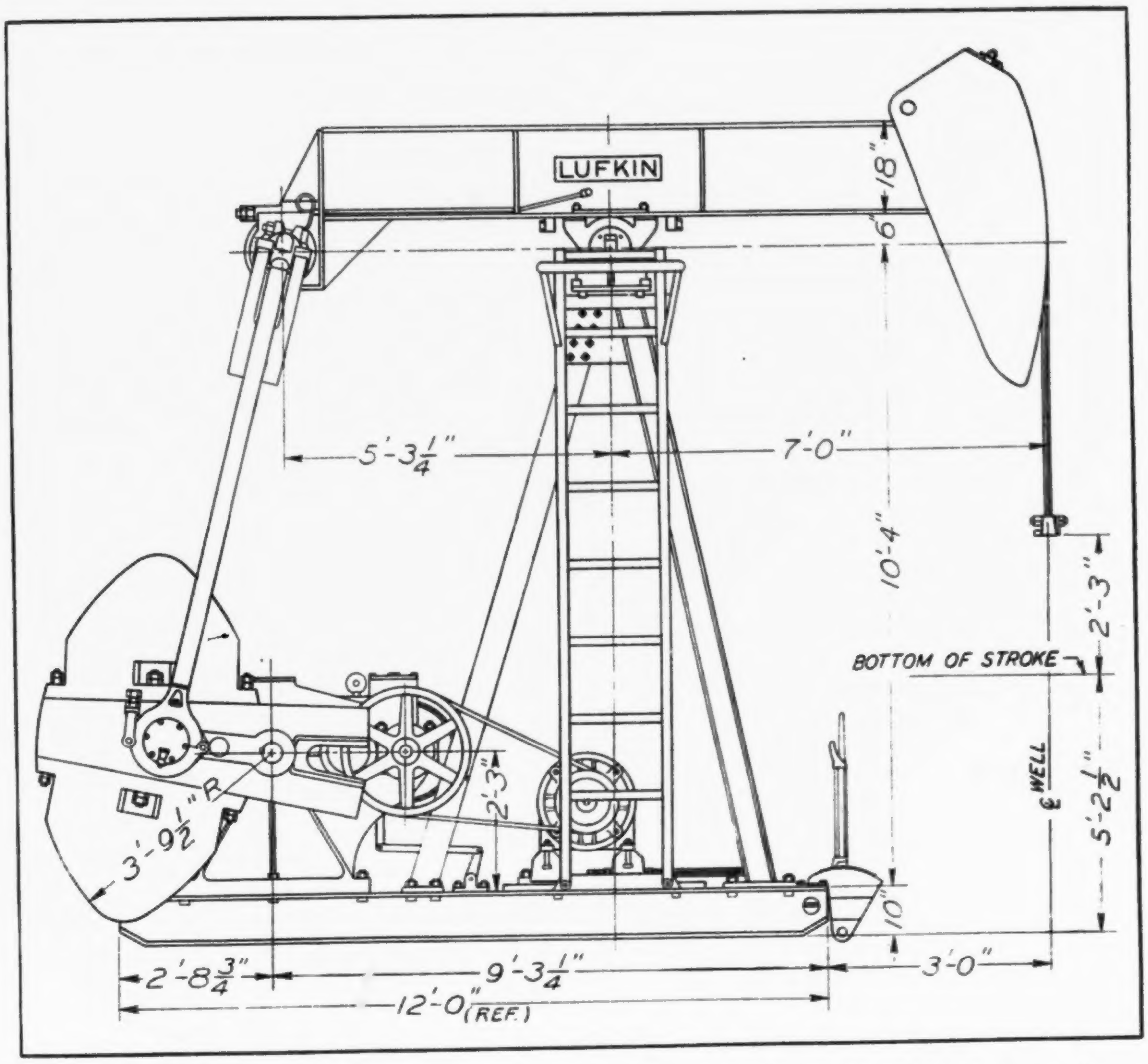
The drawing of a single part providing a complete and accurate description by means of carefully selected views and well located dimensions with the inclusion of necessary working notes is known as a DETAIL DRAWING.

The drawings you have done up to this point, which have included the above requirements, can be classified as working drawings.

Working drawings are used in the shop to produce the described part. Sometimes a drawing may be prepared for use by a particular workman,as the patternmaker, hammersmith (forge operations), machinist, etc. (See figure 1) These drawings include specialized notes related to the particular trade.

It is standard practice to make each detail on a separate sheet (size A),especially when the part may have several different applications. When several parts are to be used on a single machine, it is sometimes good practice to include several details on a large sheet.

Assembly Drawings

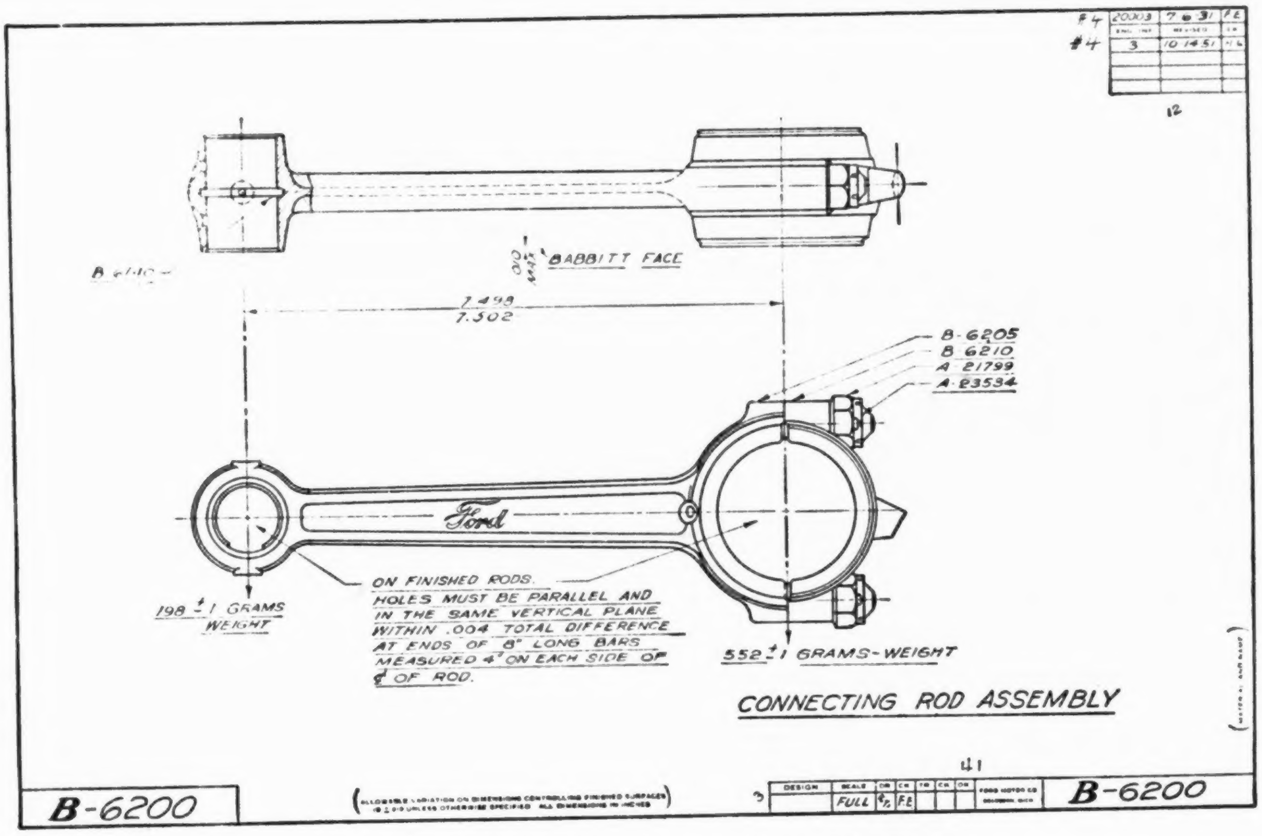


An outline assembly drawing. (*Lufkin Foundry & Machine Company*)

Figure 2.

A drawing of a completely assembled construction is called an ASSEMBLY DRAWING. The completeness of detail and dimensions vary greatly with the complexity of detail. Usually, however, only those dimensions and details which relate overall size, assembly procedures, or operating functions of the total assembly are given.

In figure 2 the detail parts are merely outlined in their relative positions and RELATE THE FUNCTIONAL RELATIONSHIP OF THE SEVERAL PARTS TO ONE ANOTHER. This is the true purpose of an assembly drawing of any type.

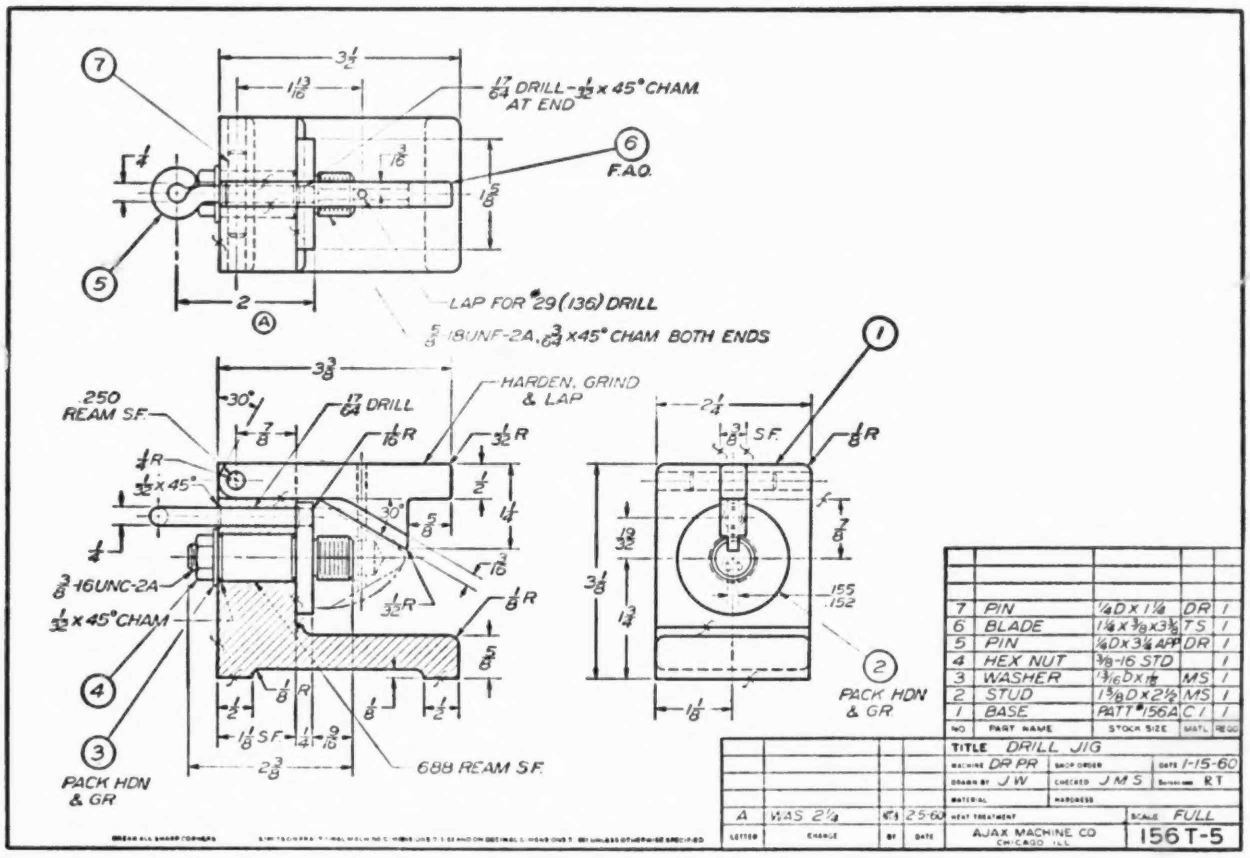

#4 20003 7-6-31 F.E.
#4 3 10-14-51
12
BABBITT FACE
7.498
7.502
B-6205
B-6210
A-21799
A-23534
Ford
198 ± 1 GRAMS WEIGHT
ON FINISHED RODS.
HOLES MUST BE PARALLEL AND IN THE SAME VERTICAL PLANE WITHIN .004 TOTAL DIFFERENCE AT ENDS OF 8" LONG BARS MEASURED 4" ON EACH SIDE OF ℄ OF ROD.
552 ± 1 GRAMS-WEIGHT
CONNECTING ROD ASSEMBLY
41
B-6200
DESIGN
SCALE
FULL
F.E.
B-6200

Assembly Drawing of Connecting Rod.

Figure 3.

In all cases assembly drawings are used to some extent as working drawings since they do supply much necessary information, particularly in a pictorial manner. Sub-assembly drawings showing only two or three functionally related parts of an entire machine are made quite often to assume proper "fit" with the other parts in later assembly. (See figure 3.)

Total assemblies, giving detail part dimensions, are made only when the parts are of a relatively uncomplicated structure and the entire assembly is to perform an easy-to-understand operation. Such drawings usually require some previous working knowledge either of the purpose for which the part is designed,or of the nature and applied use of the part in relationship to previously known methods of operation.



7
6
5
4
3
2
1
F.A.O.
$\frac{17}{64}$ DRILL-$\frac{1}{32}$x 45° CHAM AT END
LAP FOR #29(.136) DRILL
$\frac{5}{8}$-18UNF-2A, $\frac{3}{64}$x45° CHAM BOTH ENDS
HARDEN, GRIND & LAP
.250 REAM S.F.
$\frac{17}{64}$ DRILL
$\frac{3}{8}$-16UNC-2A
$\frac{1}{32}$x 45° CHAM
PACK HDN & GR
.688 REAM S.F.
.155 .152
7 PIN ¼D x 1¼ DR 1
6 BLADE 1¼ x ⅜ x 3⅛ TS 1
5 PIN ¼D x 3¼ APP DR 1
4 HEX NUT ⅜-16 STD 1
3 WASHER 1³⁄₁₆D x ⅛ MS 1
2 STUD 1⅝D x 2½ MS 1
1 BASE PATT #156A C I 1
NO PART NAME STOCK SIZE MATL REQD
TITLE DRILL JIG
MACHINE DR PR
DATE 1-15-60
DRAWN BY J W
CHECKED J M S
SCALE FULL
A WAS 2¼ 2-5-60
AJAX MACHINE CO CHICAGO ILL
156 T-5

Working Drawing Assembly of Drill Jig.

Figure 4.

Figure 4 shows an example of working drawing assembly. Note the incorporation of the parts list into the title information. Proper identification of parts in assembly drawings depends upon the completeness of the information given in the title block,and its relationship by means of identification numbers to the various views.

Use of Auxiliary Hole Legend

In addition to the incorporation of a parts list on assembly drawings, detail production drawings also can be clarified by the use of expanded title information.

Through the use of an auxiliary hole legend,the detail drawing is made easier to read by the delineation of notes for hole description from the views of the object and by placing them in the title strip. Capital letters are used for references both at the view detail and in the title block for hole descriptions, to avoid confusion with numbers which are used as the reference system to identify parts. As with the parts list, the information is read from the border inward on the drawing.

Production Drawings

A good working detail or a good assembly drawing supplies all necessary information for part of or a total machine in an orderly manner to the person responsible for the production of that part. Therefore, either of the two mentioned methods of drawing may be referred to as PRODUCTION DRAWINGS.

The workman today is only to be considered responsible for the proper manufacture of the part according to the information supplied on the drawing. The machinist should not have to concern himself with engineering problems such as whether the part will "fit other parts", or if it is "functionally related" to the purpose for which it was intended. These are problems which must be solved at the drawing board.

As we have seen in previous lessons, the draftsman has at his disposal many sources of information which will help him to:

1. properly lay out effective descriptive views of an object in his designs.
2. show by dimensions and notes the relationship of parts described.
3. give pertinent information related to a particular trade in the manufacture of his design.

The draftsman must reason out by SCIENTIFIC means how a new product should be developed to suit a particular need, and combine this with EMPIRICAL information gained by experience in the design of products.

Scientific design involves the application of the principles of physics, mathematics, chemistry, mechanics, and other sciences in the design of structures intended to serve under particular conditions.

Empirical design incorporates the practical experience of other persons: for example, in the applications of certain types of materials, and the structural requirements for the successful use of these materials in the production of new products. All design work is a combination of scientific and empirical knowledge. The draftsman today needs a good scientific background and should have access to handbooks related to his field of work. One example is the use of the Machinist's Handbook to supply related technical information.

No one person today, the draftsman included, can hope to be successful by working independently of other persons. Make it a habit to apply information found in texts, appendices, tables, charts, and handbooks in your drawing work. This is the only way you can hope to achieve technically sound results in your drawings.

Learn the application of the principles outlined in this lesson and add them to your present knowledge of drawing. Continually strive to improve your work.

Your drawings should be checked for the following before submitting them to the instructor:

1. Does the detail in your drawing display soundness of design structure?
2. Have you chosen the most effective views?
3. Is your dimensioning complete in its description of the object?
4. Have you used standard parts where possible?
5. Are all required notes included?
6. Are all clearances and tolerances for working parts clearly indicated?
7. Is your title block information complete?
8. Have you used standard abbreviations where possible?

More will be said concerning the improvement of descriptive techniques in detail and assembly drawings in successive lessons.

QUESTIONS:

The following are answered by this lesson and information found in the references referred to at the beginning of this lesson.

1. What is another name for a working drawing?

2. What is meant by "scientific design"?

3. What is meant by "empirical design"?

4. What is the purpose of a "hole legend"? Where is it normally placed?

5. How do you place and read information in a parts list located at the lower right corner of the page?

6. What is done concerning standard parts on working drawings?

7. Why must your name appear in the title block?

8. Where can you find a list of standard abbreviations used on drawings?

9. What is another name for an installation assembly?

10. What dimensions are generally included on assembly drawings?

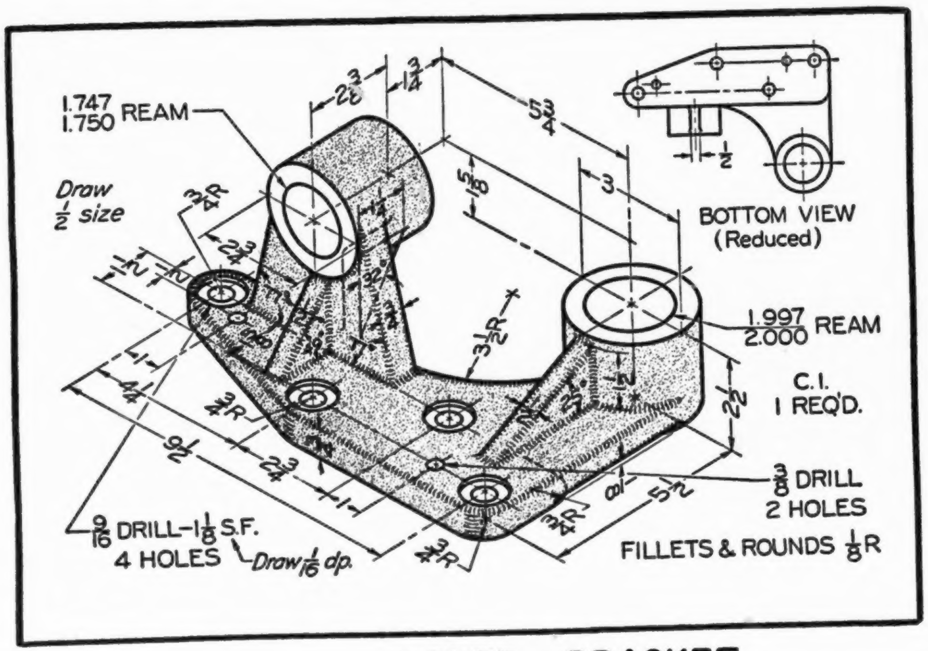
ASSIGNMENT:

Problems 1-6 are to be drawn on size B paper using the working drawing title block. Not all problems are required, but do as many as you can in the time alloted for this lesson.

You are to use the auxiliary hole legend to describe all holes on these parts.

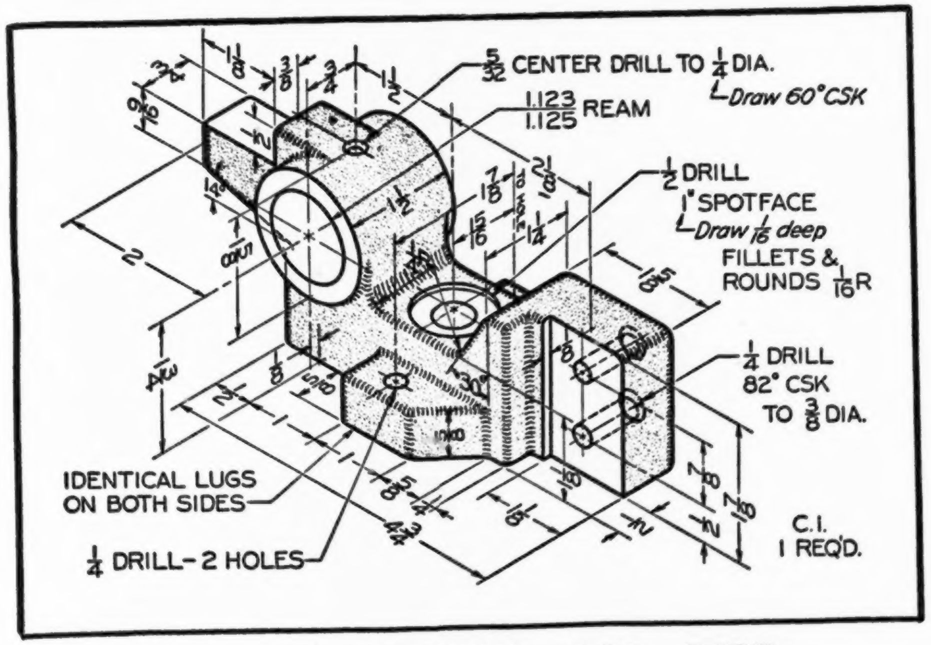
Use partial views where possible. The following suggestions are given for these problems in describing necessary detail. You must find the reason certain views are suggested and what portions should be drawn.

Problem 1 - Draw front, top, and partial views from both the left and right sides.
Problem 2 - Draw front, top, and partial right side views.
Problem 3 - Draw front, top, and partial bottom views.
Problem 4 - Draw front, top, and partial right side views.
Problem 5 - Draw top, partial front, and right side views. Follow suggestions for $\frac{1}{4}$ scale drawings.
Problem 6 - Draw top and partial front views. Add partial left and right side views. Draw $\frac{1}{2}$ scale.

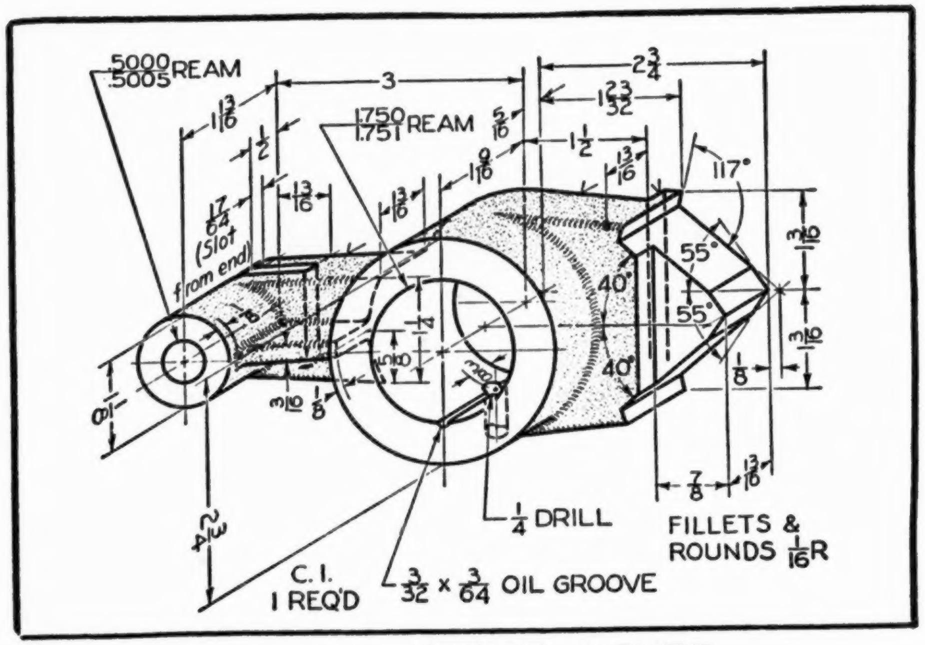

$\frac{1.747}{1.750}$ REAM
Draw $\frac{1}{2}$ size
$2\frac{3}{8}$
$1\frac{3}{4}$
$5\frac{3}{4}$
$1\frac{5}{8}$
3
$\frac{3}{4}$R
$2\frac{3}{4}$
$\frac{1}{2}$
BOTTOM VIEW (Reduced)
$3\frac{1}{2}$R
$\frac{1.997}{2.000}$ REAM
C.I.
1 REQ'D.
$2\frac{1}{2}$
$4\frac{1}{4}$
$9\frac{1}{2}$
$2\frac{3}{4}$
1
8
$5\frac{1}{2}$
$\frac{3}{8}$ DRILL
2 HOLES
$\frac{9}{16}$ DRILL-$1\frac{1}{8}$ S.F.
4 HOLES
Draw $\frac{1}{16}$ dp.
FILLETS & ROUNDS $\frac{1}{8}$R

LEVER BRACKET

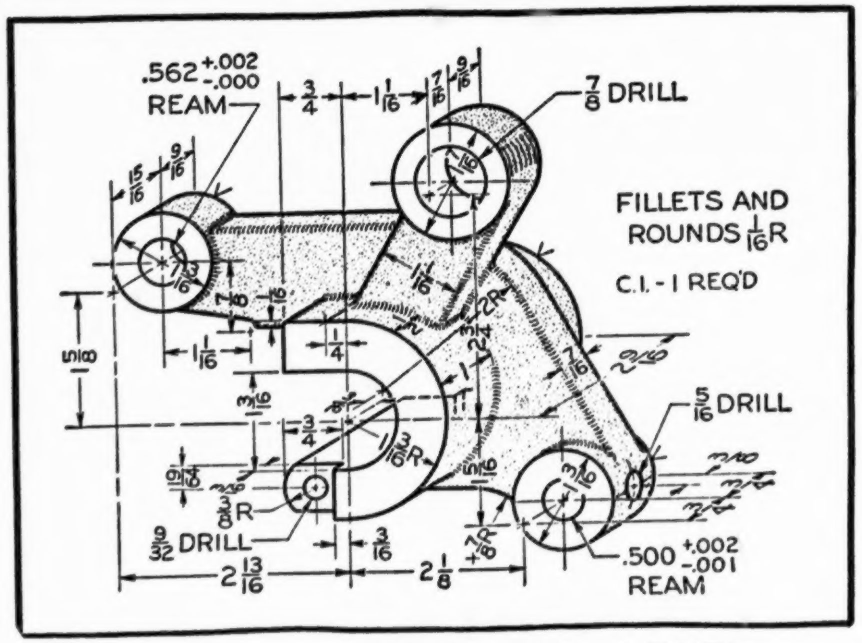
Problem 1.


$\frac{5}{32}$ CENTER DRILL TO $\frac{1}{4}$ DIA.
Draw 60° CSK
1.123 / 1.125 REAM
$\frac{1}{2}$ DRILL
1" SPOTFACE
Draw $\frac{1}{16}$ deep
FILLETS & ROUNDS $\frac{1}{16}$R
$\frac{1}{4}$ DRILL
82° CSK
TO $\frac{3}{8}$ DIA.
C.I.
1 REQ'D.
IDENTICAL LUGS ON BOTH SIDES
$\frac{1}{4}$ DRILL-2 HOLES
30°
2
$4\frac{3}{4}$

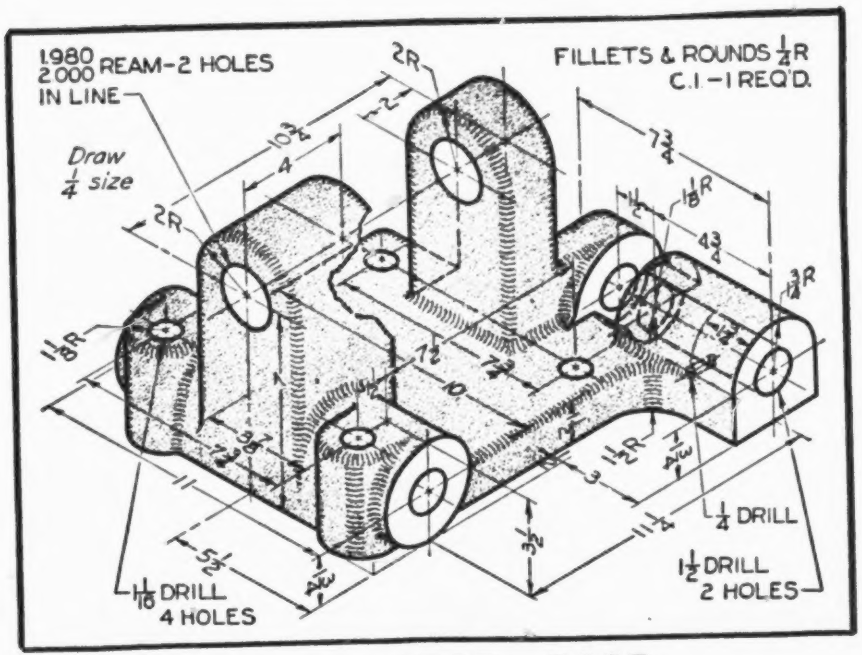
Problem 2. **GRIPPING ROD BASE**


.5000 / .5005 REAM
3
1.750 / 1.751 REAM
$2\frac{3}{4}$
$1\frac{23}{32}$
$1\frac{1}{2}$
117°
55°
55°
40°
40°
$\frac{17}{64}$ (Slot from end)
$\frac{1}{4}$ DRILL
FILLETS & ROUNDS $\frac{1}{16}$R
C.I.
1 REQ'D
$\frac{3}{32}$ x $\frac{3}{64}$ OIL GROOVE
$2\frac{3}{4}$

Problem 3. **SWITCH LEVER**

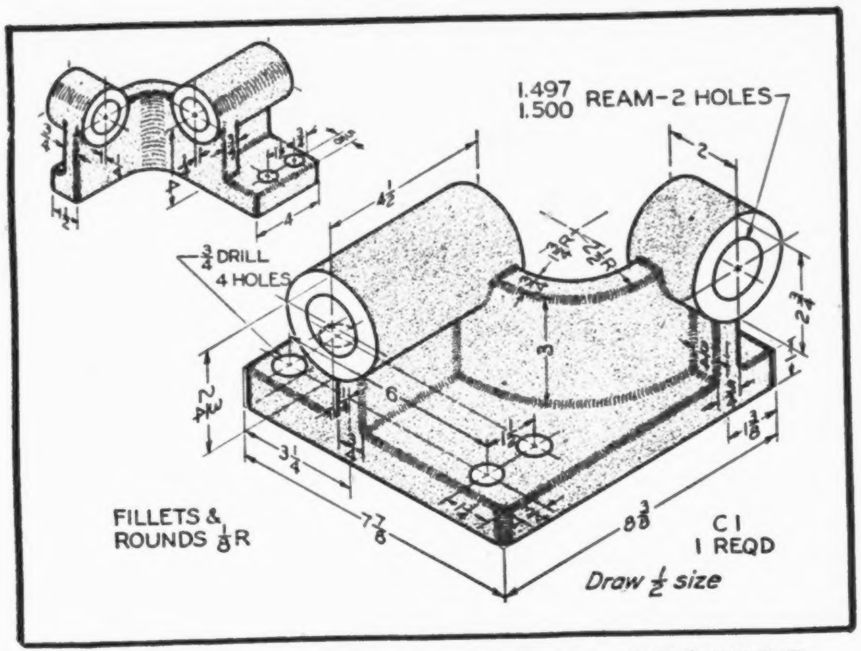

.562 +.002 / -.000 REAM
$\frac{7}{8}$ DRILL
FILLETS AND ROUNDS $\frac{1}{16}$R
C.I. - 1 REQ'D
$\frac{5}{16}$ DRILL
$\frac{3}{8}$R
$\frac{9}{32}$ DRILL
$2\frac{13}{16}$
$2\frac{1}{8}$
.500 +.002 / -.001 REAM

Problem 4. **FORM ROLL LEVER**


1.980 / 2.000 REAM-2 HOLES IN LINE
Draw 1/4 size
2R
FILLETS & ROUNDS 1/4R
C.I.-1 REQ'D.
1 1/8 DRILL 4 HOLES
1/4 DRILL
1 1/2 DRILL 2 HOLES

STOP BASE

Problem 5.


1.497 / 1.500 REAM-2 HOLES
3/4 DRILL 4 HOLES
FILLETS & ROUNDS 1/8R
C I
1 REQD
Draw 1/2 size

LEAD SCREW BRACKET

Problem 6.

UNIT V - SECTIONS AND RELATED CONVENTIONS

Sectioning Techniques

Lesson 1

OBJECTIVES:

1. To define sections and the term "conventions."
2. To introduce the visualization of sectional views.
3. To introduce the use of cutting plane.
4. To introduce the use of section lines.

REFERENCES:

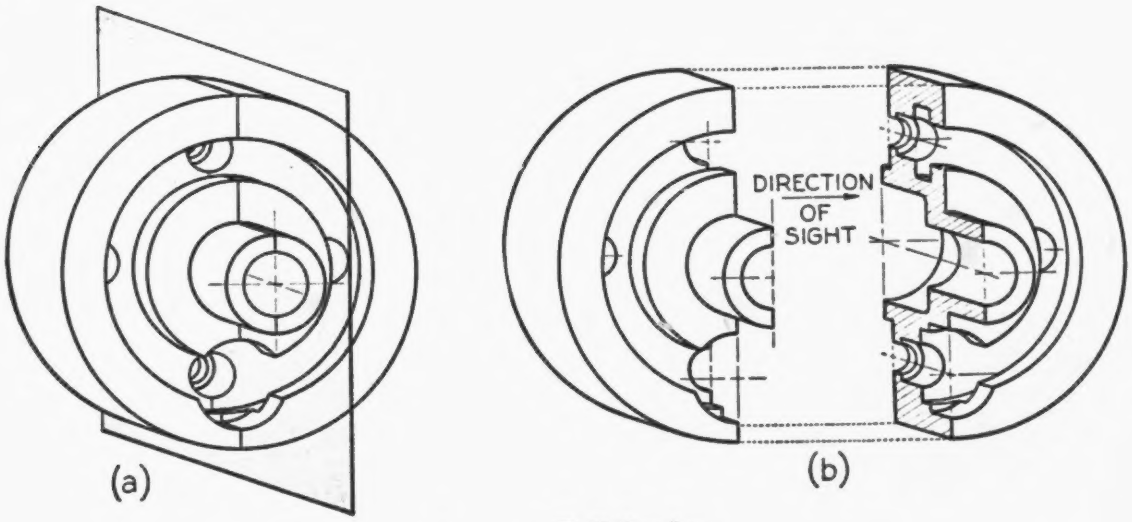
1. Chapter 7, TECHNICAL DRAWING, Giesecke, Mitchell, and Spencer.
2. Chapter 8, MECHANICAL DRAWING, French.

INFORMATION:

Through the use of projected views of objects as discussed in previous lessons, the exterior features of even the most complicated objects can be adequately described. However, the use of hidden lines hinders the production of understandable views of complicated interior structures. Therefore, it is necessary for the following reasons to provide "section" views of objects:

1. To show clearly the interior of objects.
2. To represent clearly the relationship of internal features of an object in reference to external features.
3. To provide object lines to which dimensions may refer.

Sections

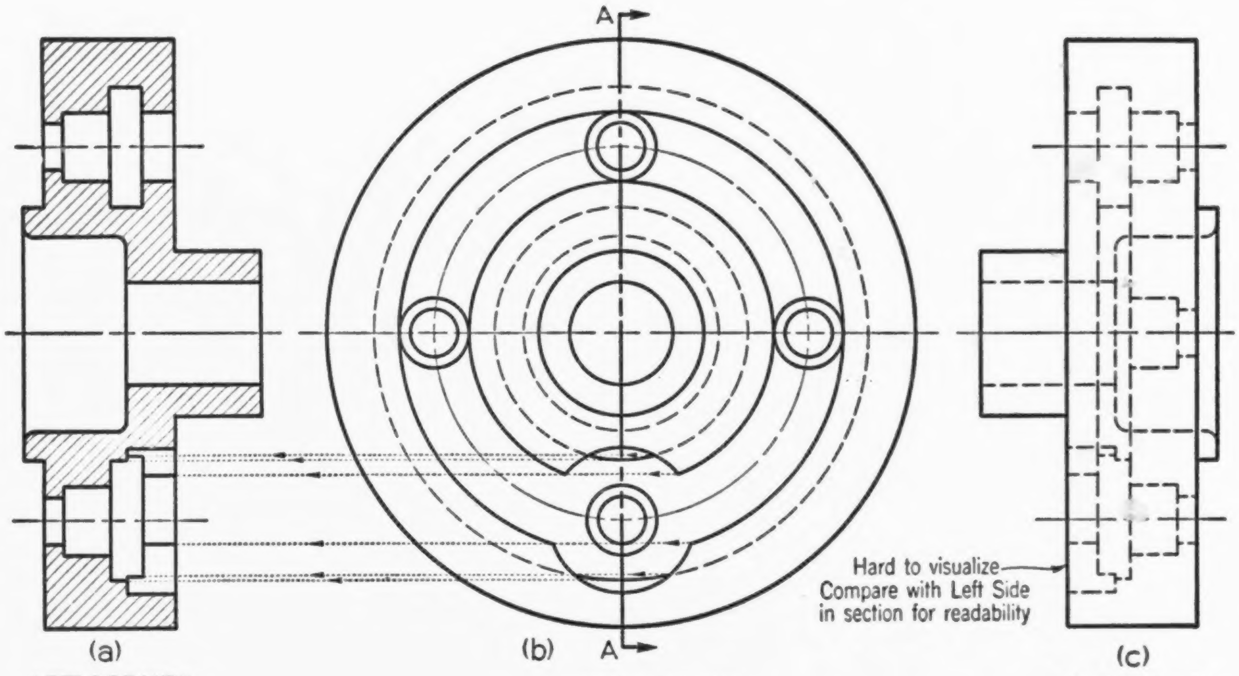


Full Section.

Figure 1.

A "section" of an object is a view of its internal features obtained by cutting through the object and projecting the cut surface (figure 1b). An imaginary "cutting plane" or point at which the view is to be obtained is first established (figure 1a), giving a reference from which the view is projected.

Lines in Section Views



(a) LEFT SIDE VIEW IN FULL SECTION

(b) FRONT VIEW

(c) RIGHT SIDE VIEW

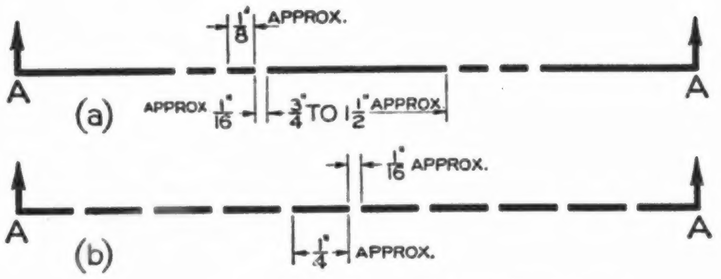
Full Section.

Figure 2.

The primary purpose of a section view is to present a clear representation of the interior features of an object. Therefore, only those lines which are located directly on the cutting plane are shown in the "section." In figure 2 the object is "cut" through at center, with the left side of the object considered to be disposed of in the front view to yield the left side "section." Note, however, that the entire front view is drawn and no portion or feature is omitted or changed. Note the comparison of the "section" with the regular right side view of this object as far as clarity is concerned.

You will notice also that all hidden lines are omitted in the section view. This is true of all regular "section" views, in keeping with the rule that no lines either forward of or behind the cutting plane are shown in "sections" which are not directly visible. Be careful to include all features, such as edges, directly visible behind the cutting plane.

Cutting Planes



Cutting-Plane Lines (Full Size).

Figure 3.

Figure 3 shows two forms of cutting plane lines which are used for indicating the point from which a section view is obtained. Figure 3a shows the style of line which has been in general use for a long period of time. Figure 3b shows the style composed of short dashes which has the advantage of showing up clearly on complicated forms. Pay particular attention to the dimensions given for the length of the "dashes" in each style. They must be drawn accurately. Arrowheads are used at the ends of the line to indicate the direction of view. Use of the capital letters will be explained in lesson 3 in connection with the drawing of multiple sections.

Sections Lines

In order to represent clearly the surfaces of the object which are located directly on the cutting plane, shading in the form of closely spaced "section" lines is used. These lines are "thin" in comparison to the other lines on the drawing. Only the surfaces "cut" by the plane are shaded, not visible surfaces behind the "cutting plane."

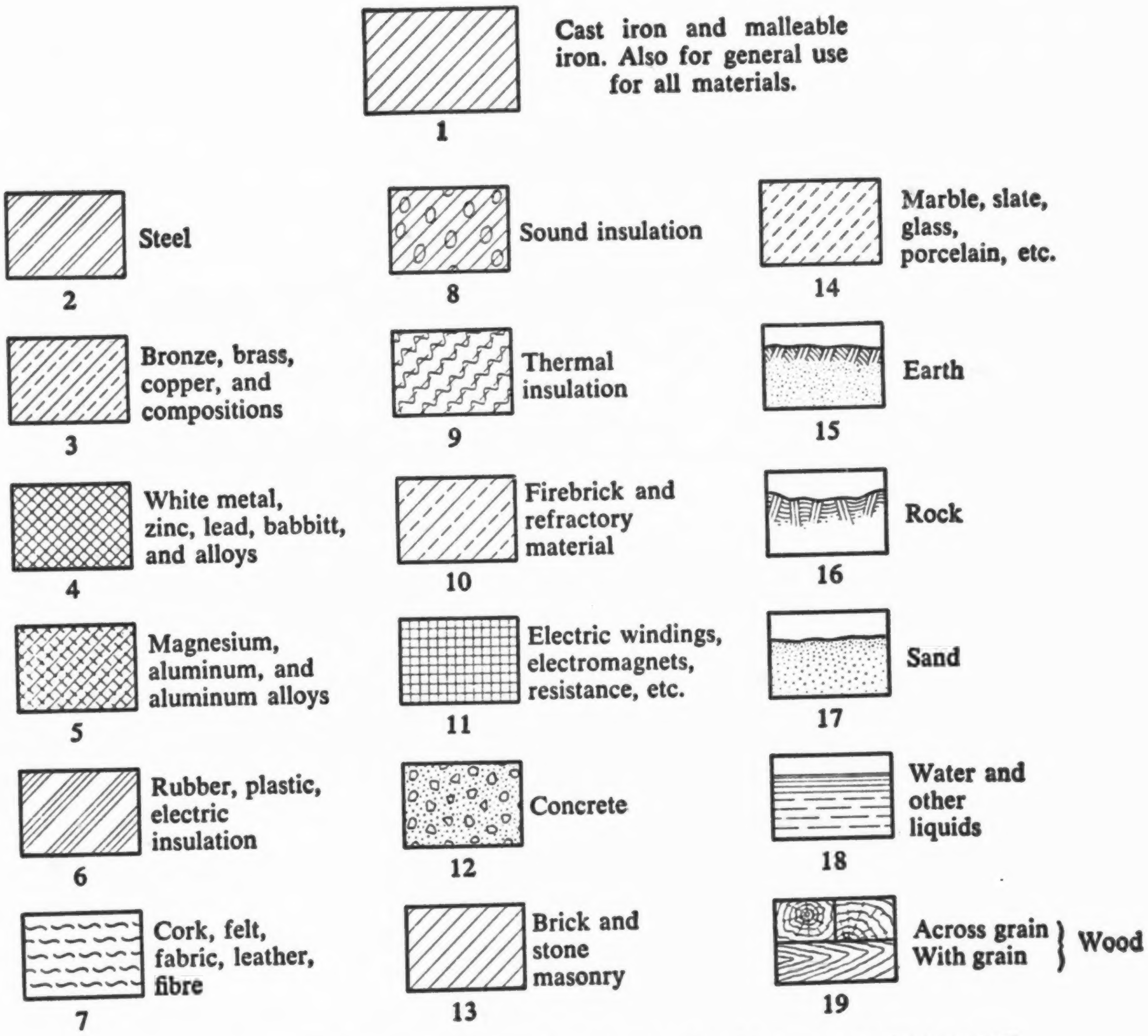
In past drawing practice, several types of section lines were used to describe various materials (figure 4). However, since there are a number of different kinds of each material today, and a note must necessarily accompany each "section" to define the variety of each material indicated, it has become advisable to use "general purpose" section lines for all single detail drawings of any material representation. This symbol is the one generally used for cast iron (figure 4-1) in assembly drawings.

Symbolic section lines are used for assembly drawings only where it is necessary to distinguish different materials.

Spacing of Section Lines

Standardly, "general purpose" section lines are spaced $\frac{3}{32}$" apart. However, for small sectioned areas the lines may be spaced closer, $\frac{1}{16}$";

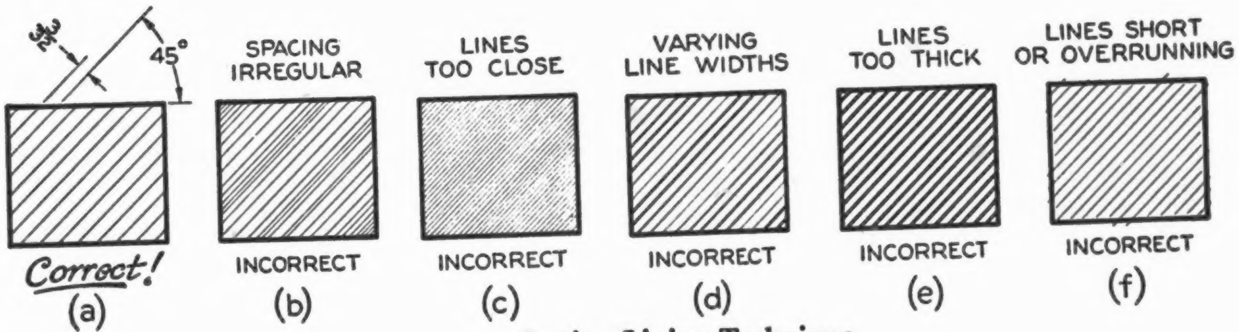
and for larger areas the lines may be spaced further apart, $\frac{1}{8}$". If in doubt, follow standard spacing practice.


Cast iron and malleable iron. Also for general use for all materials.
1
Steel
2
Bronze, brass, copper, and compositions
3
White metal, zinc, lead, babbitt, and alloys
4
Magnesium, aluminum, and aluminum alloys
5
Rubber, plastic, electric insulation
6
Cork, felt, fabric, leather, fibre
7
Sound insulation
8
Thermal insulation
9
Firebrick and refractory material
10
Electric windings, electromagnets, resistance, etc.
11
Concrete
12
Brick and stone masonry
13
Marble, slate, glass, porcelain, etc.
14
Earth
15
Rock
16
Sand
17
Water and other liquids
18
Across grain
With grain
Wood
19

American Standard Symbols for Section Lining (ASA Y14.2-1957).

Figure 4.

Care in Drawing Section Lines


$\frac{1}{16}$"
45°
SPACING IRREGULAR
LINES TOO CLOSE
VARYING LINE WIDTHS
LINES TOO THICK
LINES SHORT OR OVERRUNNING
Correct!
INCORRECT
INCORRECT
INCORRECT
INCORRECT
INCORRECT
(a)
(b)
(c)
(d)
(e)
(f)

Section-Lining Technique.

Figure 5.

Be sure that section lines extend fully to the enclosing object lines (figure 5f) but do not extend past them.

The line weight and spacing must be consistent.

All section lines are ordinarily drawn at a 45° angle. The angle at which section lines are drawn may be changed if they fall parallel to, or nearly parallel to, adjacent object lines. All lines in a given view of a single part are drawn in the same direction even if they are located in isolated areas of the same view.

Possible Sections

Section views of objects may be obtained from any direction of view as long as an accompanying cutting plane is given in an adjacent view. Various types of sections are explained in the following four lessons.

"Conventions"

Conventional drawing procedures, referred to as "conventions" of drawing*, are those which have been established to provide the simplest and clearest representations of various object forms.

Where section drawings are concerned, some related "conventions" will be explained as necessary in the following lessons on sections.

QUESTIONS:

1. What is a "section" of an object?
2. How do you locate the area on an object of a desired section?
3. Draw a sample "cross-hatched" ("sectioned") area about 1" square using "general purpose" section lines.
4. What is done concerning hidden lines in a "section"?
5. At what angle are section lines ordinarily drawn?
6. Why are arrowheads used on "cutting planes"?
7. What is meant by a "convention"?

---

* See pages 186-187, TECHNICAL DRAWING, Giesecke, Mitchell, Spencer.

8. What material is represented by "general purpose" section lines?

9. What is the correct spacing for "general purpose" section lines?

10. What areas are "shaded" using section lines?

UNIT V - SECTIONS AND RELATED CONVENTIONS

Full and Half Sections

Lesson 2

OBJECTIVES:

1. To explain the projection of full and half sections.
2. To explain related "conventions" of representation for object details.

REFERENCES:

1. Chapter 7, TECHNICAL DRAWING, Giesecke, Mitchell, and Spencer.
2. Chapter 8, MECHANICAL DRAWING, French.

INFORMATION:

If a cutting plane passes completely through an object, a full section is produced.* For symmetrical objects, the cutting plane is usually located at the center point in order to relate the full height or full diameter of the object as the case may require.

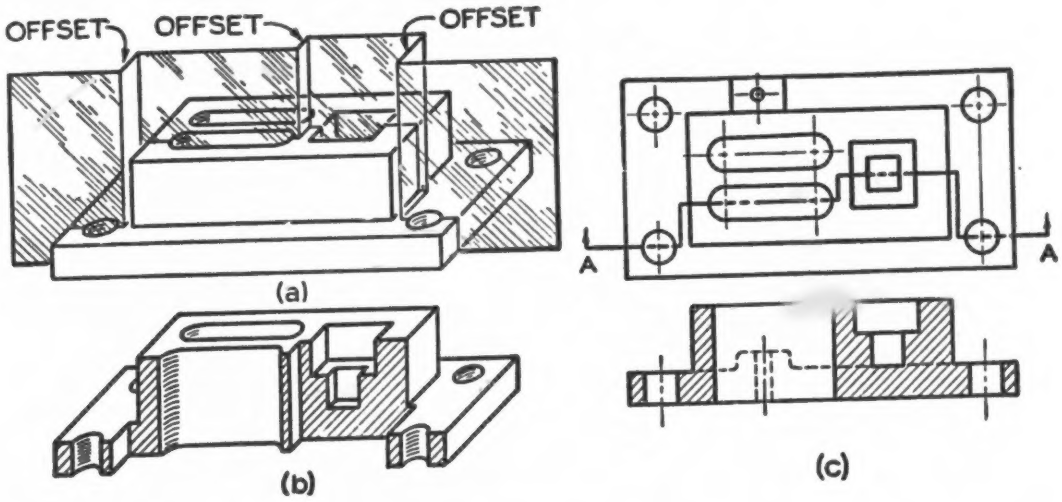


Figure 1.

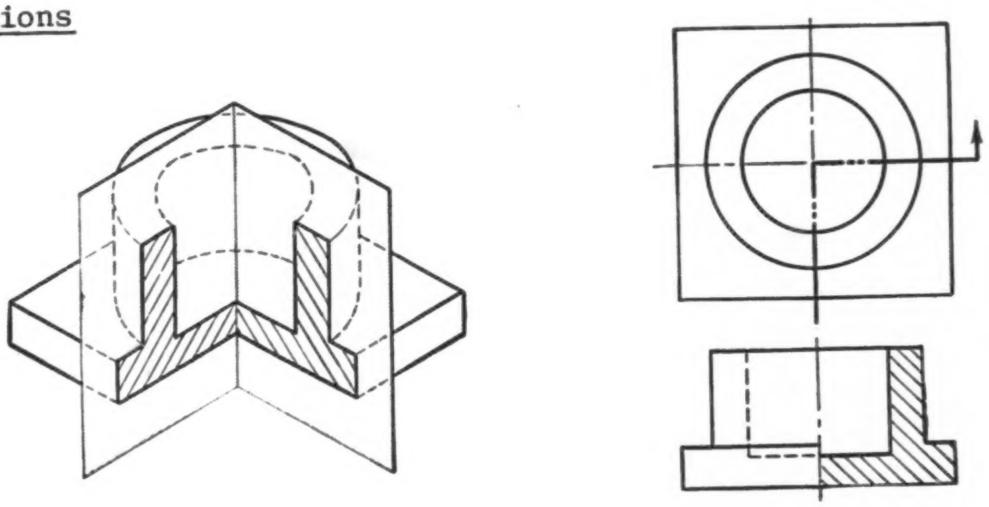
By placing the cutting plane at the center of the object, most of the critical features of the object are usually described. However, in cases of irregular objects, adequate description of detail cannot be obtained by using a straight cutting plane (figure 1). Therefore, it is necessary to "offset" the cutting plane in several locations to include critical descriptive features. In figure 1b the front portion of the object has been removed, relating how the "cut" has been made. The cutting plane in the top view (figure 1c) indicates the direction of view for the section produced in the front view. Notice that no object lines occur where "bends" or "corners" in the cutting plane are used. All surfaces of the object are considered to be projected on the same "plane."

---

* see figure 1, p. 179

Note. FIGURE 1c SHOWS ONE DEVIATION FROM THE RULE THAT HIDDEN LINES SHOULD BE OMITTED FROM SECTIONS. The "boss" at the rear of the object in this case could not otherwise be indicated.

Half Sections

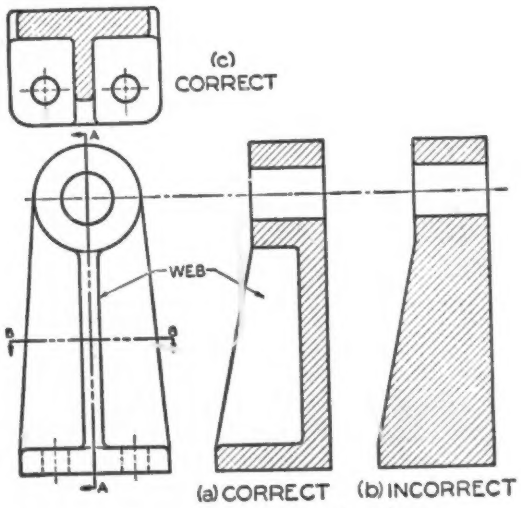


A half section.

Figure 2.

Used generally for symmetrical objects, half section views have the advantage of showing the interior of the object clearly in relationship to the exterior features (figure 2). Notice that the section is taken at the center lines removing a 90° "slice" of the object. Only one arrowhead can be included on the cutting plane, showing direction of view for half sections.

Conventions of Sections



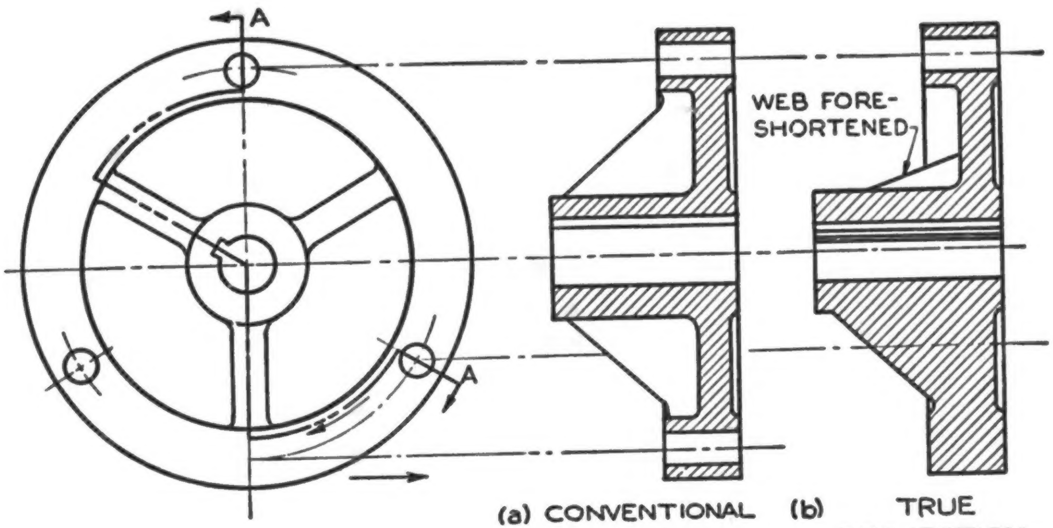
(a) CORRECT (b) INCORRECT

Webs in Section.

Figure 3.

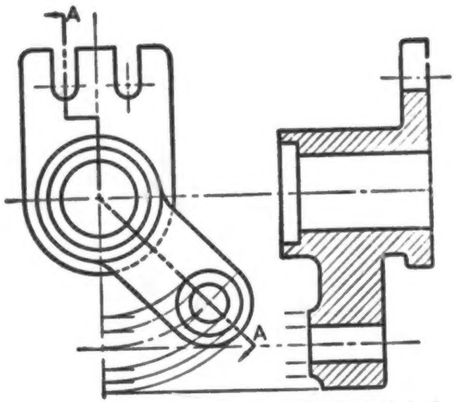
Ribs in Sections:
When cutting planes pass through "ribs" or "webs" (figure 3), they should not be sectional. Despite the fact that ribs are located at the cutting plane, a false impression of "solidity" is obtained (figure 3b) if a section through them is shown.

Revolution of Features:



(a) CONVENTIONAL METHOD-PREFERRED (b) TRUE PROJECTION-POOR PRACTICE

Figure 4. Symmetry of Webs.



SECTION A-A

Revolution.

Figure 5.

Figures 4 and 5 show where revolution of certain features in objects may be necessary to provide clear descriptions.

Notice that the cutting plane is offset (never more than 90°) to include necessary features. Where offsets occur in circular views, the cutting plane is drawn with the compass. Arrowheads are placed at right angles to the ends of the cutting plane regardless of direction or position.

The features shown in the "section" are considered to be located on a flat plane parallel to the "section" view. (FOR ADDITIONAL INFORMATION, SEE REFERENCES FOR THIS LESSON.)

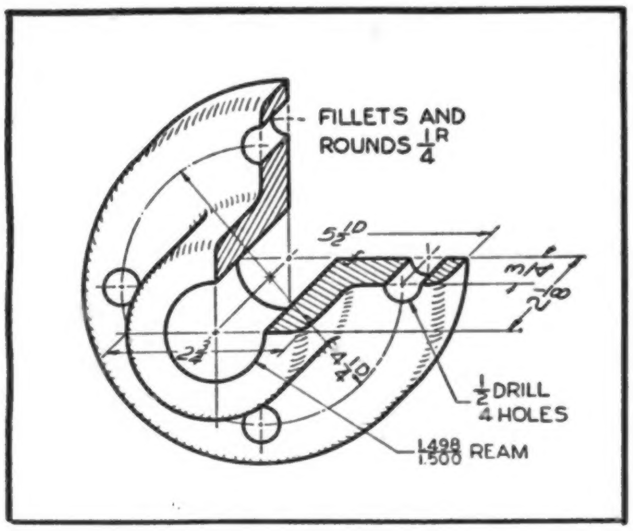
General Rules for Sections:

1. Use sections to provide additional dimensioning locations. Dimension all possible surfaces of a section view.
2. Cutting planes replace center lines. Center lines must be included on the view.
3. Revolutions of features should only be used when clarity will be increased.
4. Ribs, shafts, bolts, and cylindrical objects in general are not shown in full or half sections.
5. Cutting planes must be shown in the full view of the object adjacent to the "section."
6. Regular views of the object are replaced by section views.

ASSIGNMENT:

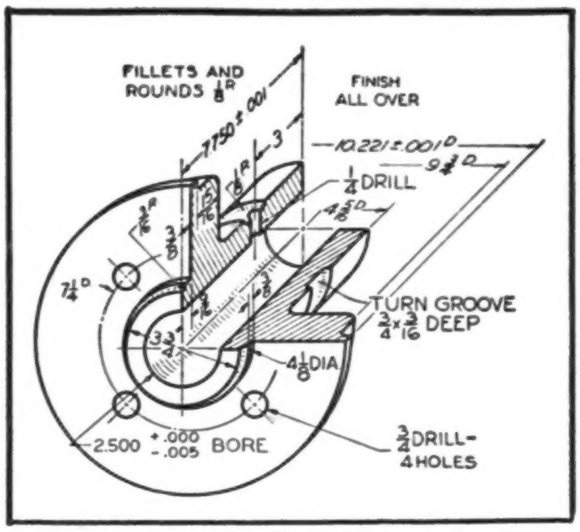
Problems 1 - 11 are to be done on size A paper using the simplified title block. Draw a front view and a right side section. Offset or revolve features as found necessary. Dimension all problems fully. Use all working drawing procedures, including auxiliary hole legends. Use reduced scales as found necessary.

Problem 12 requires a size B sheet. Draw full scale. Include front and right side views and a partial bottom view of the left lug. Provide half sections in both the front and side views.


FILLETS AND ROUNDS $\frac{1}{4}$R
$5\frac{1}{2}$D
$\frac{3}{4}$
$2\frac{1}{8}$
$2\frac{3}{4}$
$4\frac{1}{4}$D
$\frac{1}{2}$DRILL 4 HOLES
$\frac{1.498}{1.500}$ REAM

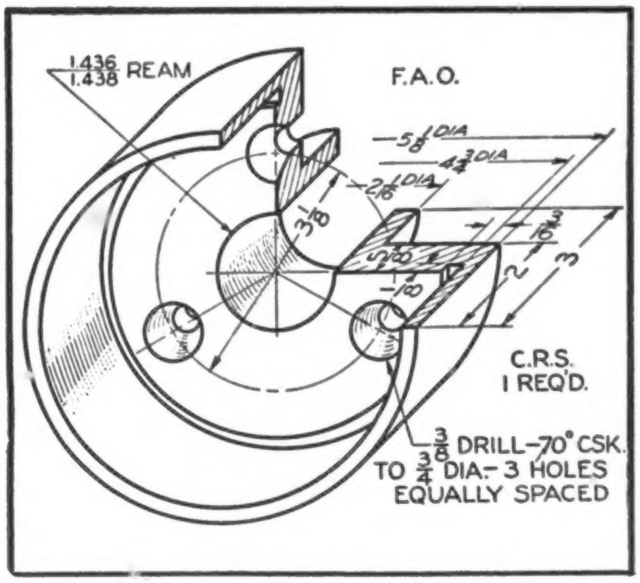
BEARING

Problem 1.


FILLETS AND ROUNDS $\frac{1}{8}$R
FINISH ALL OVER
7.750 ± .001
3
$\frac{1}{8}$R
10.221 ± .001D
$9\frac{3}{4}$D
$\frac{1}{4}$DRILL
$4\frac{5}{8}$D
$\frac{3}{16}$R
$\frac{15}{16}$
$\frac{3}{8}$
$7\frac{1}{4}$D
$\frac{3}{16}$
$\frac{3}{8}$
TURN GROOVE $\frac{3}{4}$x$\frac{3}{16}$ DEEP
$3\frac{3}{4}$
$4\frac{1}{8}$DIA
2.500 $^{+.000}_{-.005}$ BORE
$\frac{3}{4}$DRILL-4HOLES

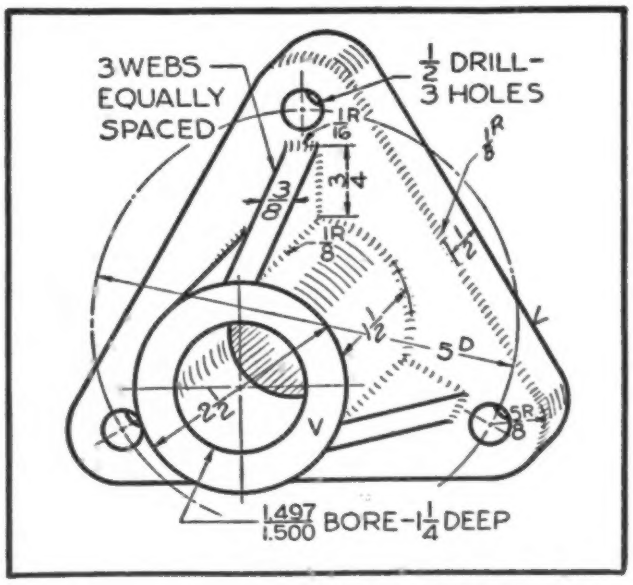
SPECIAL BEARING

Problem 2.


$\frac{1.436}{1.438}$ REAM
F.A.O.
$5\frac{1}{8}$DIA
$4\frac{3}{4}$DIA
$2\frac{1}{16}$DIA
$3\frac{1}{8}$
$\frac{3}{16}$
$\frac{5}{8}$
$\frac{1}{8}$
2
3
C.R.S. 1 REQ'D.
$\frac{3}{8}$ DRILL-70° CSK. TO $\frac{3}{4}$ DIA.-3 HOLES EQUALLY SPACED

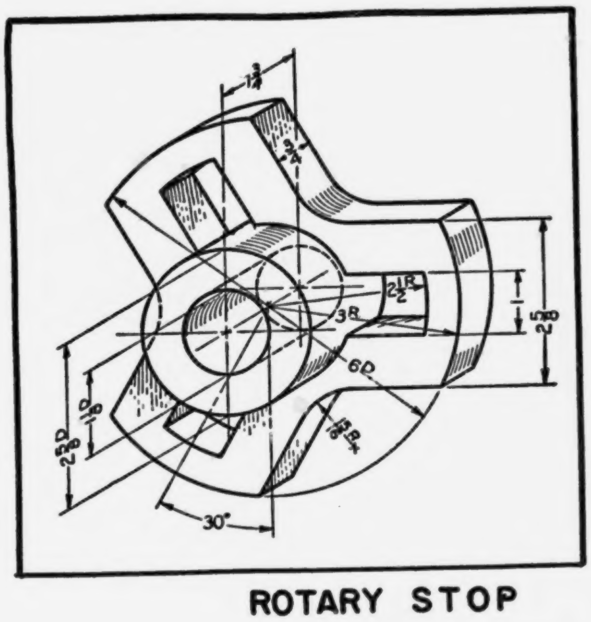
IDLER PULLEY

Problem 3.

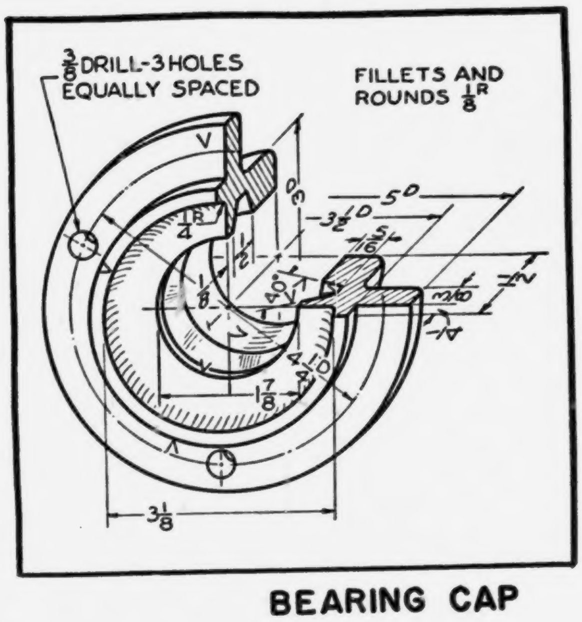

3WEBS EQUALLY SPACED
$\frac{1}{2}$ DRILL-3 HOLES
$\frac{1}{16}$R
$\frac{1}{8}$R
$\frac{3}{4}$
$\frac{3}{8}$
$\frac{1}{8}$R
$1\frac{1}{2}$
$\frac{1}{2}$
5D
$2\frac{1}{2}$
V
$\frac{5}{8}$R
$\frac{1.497}{1.500}$ BORE-$1\frac{1}{4}$DEEP

COLUMN SUPPORT

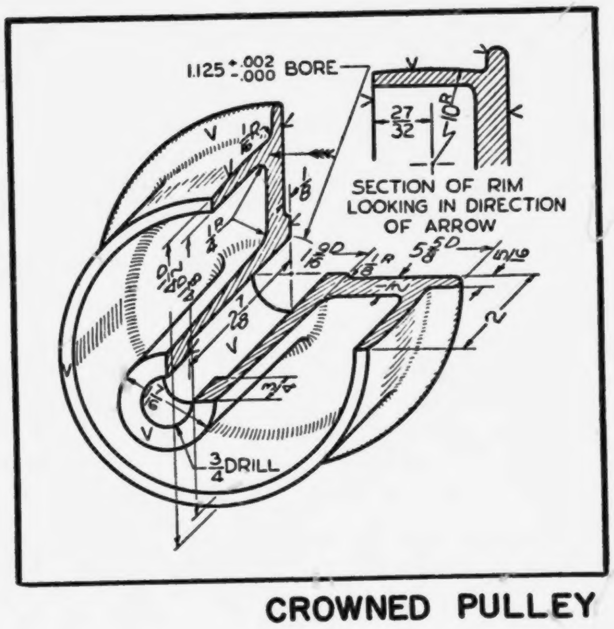
Problem 4.


ROTARY STOP
30°
6D
3R
2 1/2 R

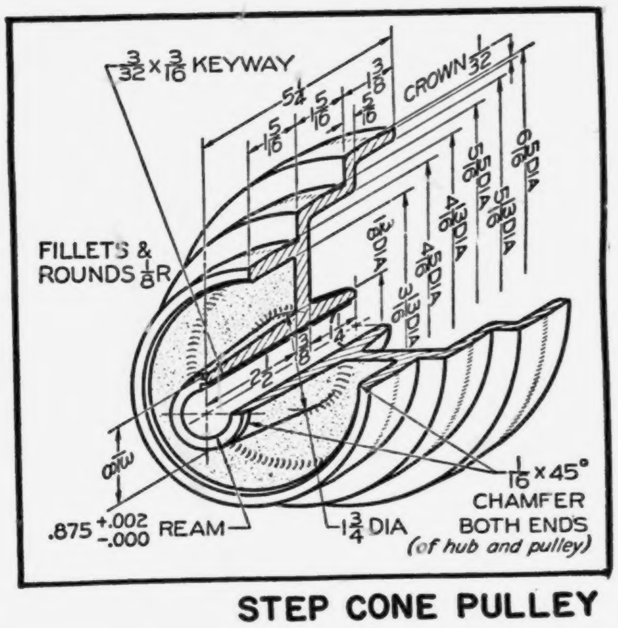
Problem 5.


BEARING CAP
3/8 DRILL-3 HOLES EQUALLY SPACED
FILLETS AND ROUNDS 1/8 R
5D
3 1/2 D
40°
1 7/8
3 1/8

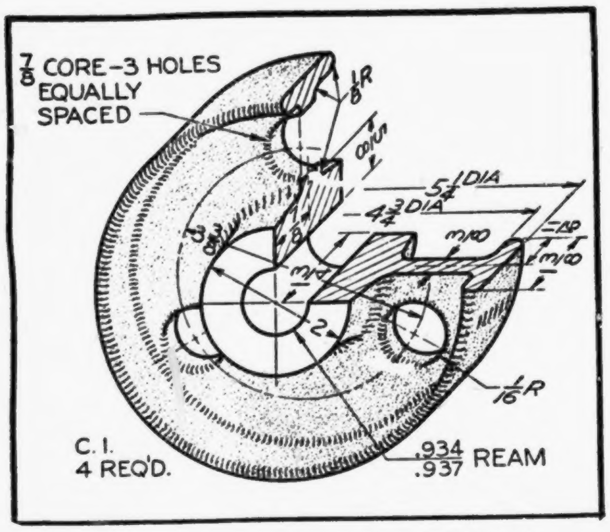
Problem 6.


CROWNED PULLEY
1.125 +.002 -.000 BORE
27/32
SECTION OF RIM LOOKING IN DIRECTION OF ARROW
5 5/8 D
3/4 DRILL

Problem 7.

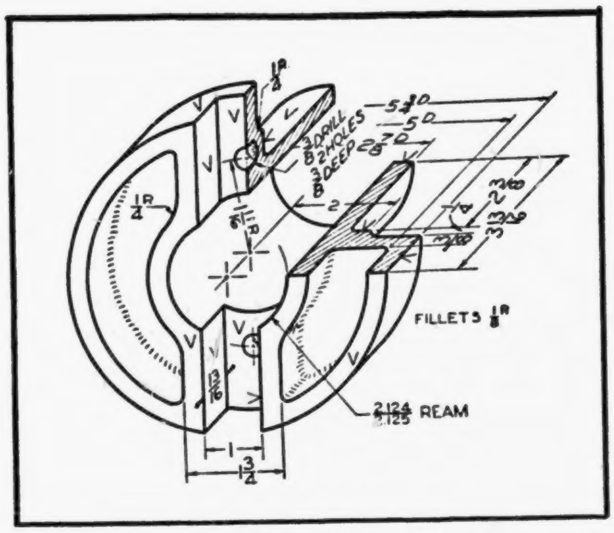

STEP CONE PULLEY
3/32 x 3/16 KEYWAY
CROWN 1/32
FILLETS & ROUNDS 1/8 R
6 5/16 DIA
5 13/16 DIA
5 5/16 DIA
4 13/16 DIA
4 5/16 DIA
3 13/16 DIA
1/16 x 45° CHAMFER BOTH ENDS (of hub and pulley)
.875 +.002 -.000 REAM
1 3/4 DIA

Problem 8.


7/8 CORE-3 HOLES EQUALLY SPACED
1/8 R
5 1/4 DIA
4 3/4 DIA
2
1/16 R
C.I.
4 REQ'D.
.934/.937 REAM

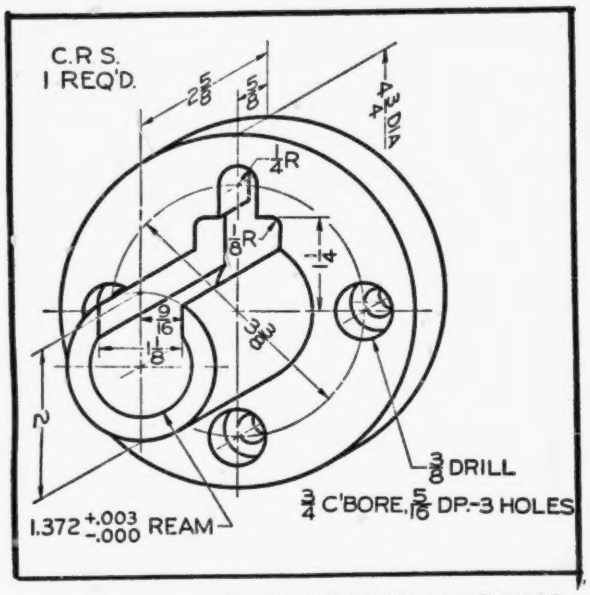
TRUCK WHEEL

Problem 9.


1/4 R
3/8 DRILL 2 HOLES 3/8 DEEP
5 3/4 D
5 D
2 5/8 D
2
1/4 R
FILLETS 1/8 R
2.124/2.125 REAM
1
1 3/4

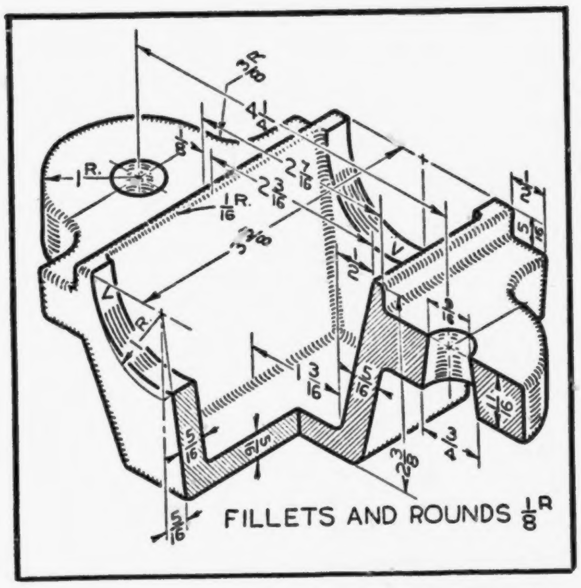
STOCK GUIDE

Problem 10.


C.R.S.
1 REQ'D.
2 5/8
5/8
4 3/4 DIA
1/4 R
1/8 R
1 1/4
9/16
1 1/8
3 3/8
2
3/8 DRILL
3/4 C'BORE, 5/16 DP.-3 HOLES
1.372 +.003/−.000 REAM

CENTERING BUSHING

Problem 11.


3/8 R
4 1/4
1 R.
1/8
2 7/16
2 3/16
1/16 R.
3 3/8
1/2
5/16
1 3/16
3 3/8
4 3/4
5/16
FILLETS AND ROUNDS 1/8 R

BEARING HOUSING

Problem 12.

UNIT V - SECTIONS AND RELATED CONVENTIONS

Revolved, Removed, Broken, and Multiple Sections

Lesson 3

OBJECTIVE:

1. To relate procedures for drawing revolved, removed, broken, and multiple sections.

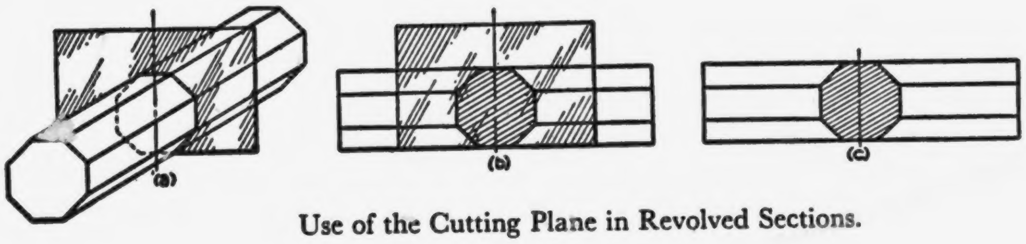
REFERENCE:

1. Chapter 7, TECHNICAL DRAWING, Giesecke, Mitchell, and Spencer.

INFORMATION:

There are many instances which occur in the drawing of objects, especially with working drawings, which require the inclusion of section views other than full or half sections. The types of sections discussed in this lesson are for the most part (except multiple sections and certain removed sections) directly related to or drawn as part of the existing views of the object.

Revolved Sections



Use of the Cutting Plane in Revolved Sections.

Figure 1.

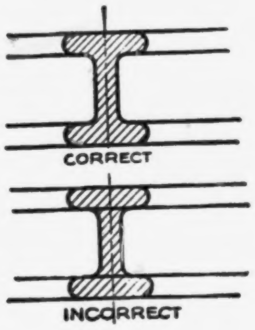


Figure 2.

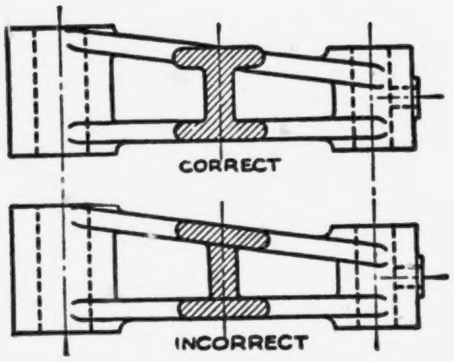
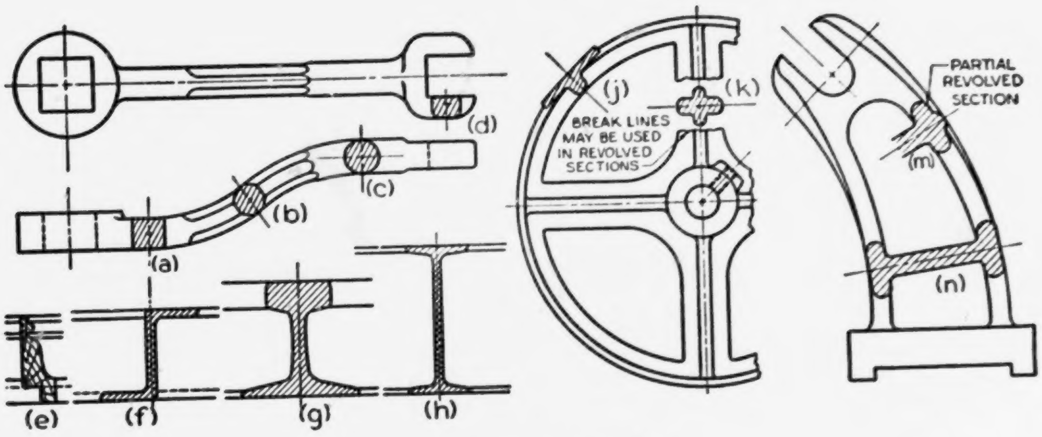


Figure 3.



Revolved Sections.

Figure 4.

Revolved sections are especially useful in describing cross sectional shapes of elongated objects, such as bars, ribs, spokes, etc. Figure 4 shows applied use of revolved sections.

Revolved sections are drawn on existing views by assuming a position perpendicular to the center line or axis of the object (figure 1a) and revolving the view 90^o at (b) about a center line (c).

The center line becomes part of the view, and object lines in the area of the revolved section are not shown (figure 2). The true form of the revolved section must be shown regardless of the form of the object (figure 3).

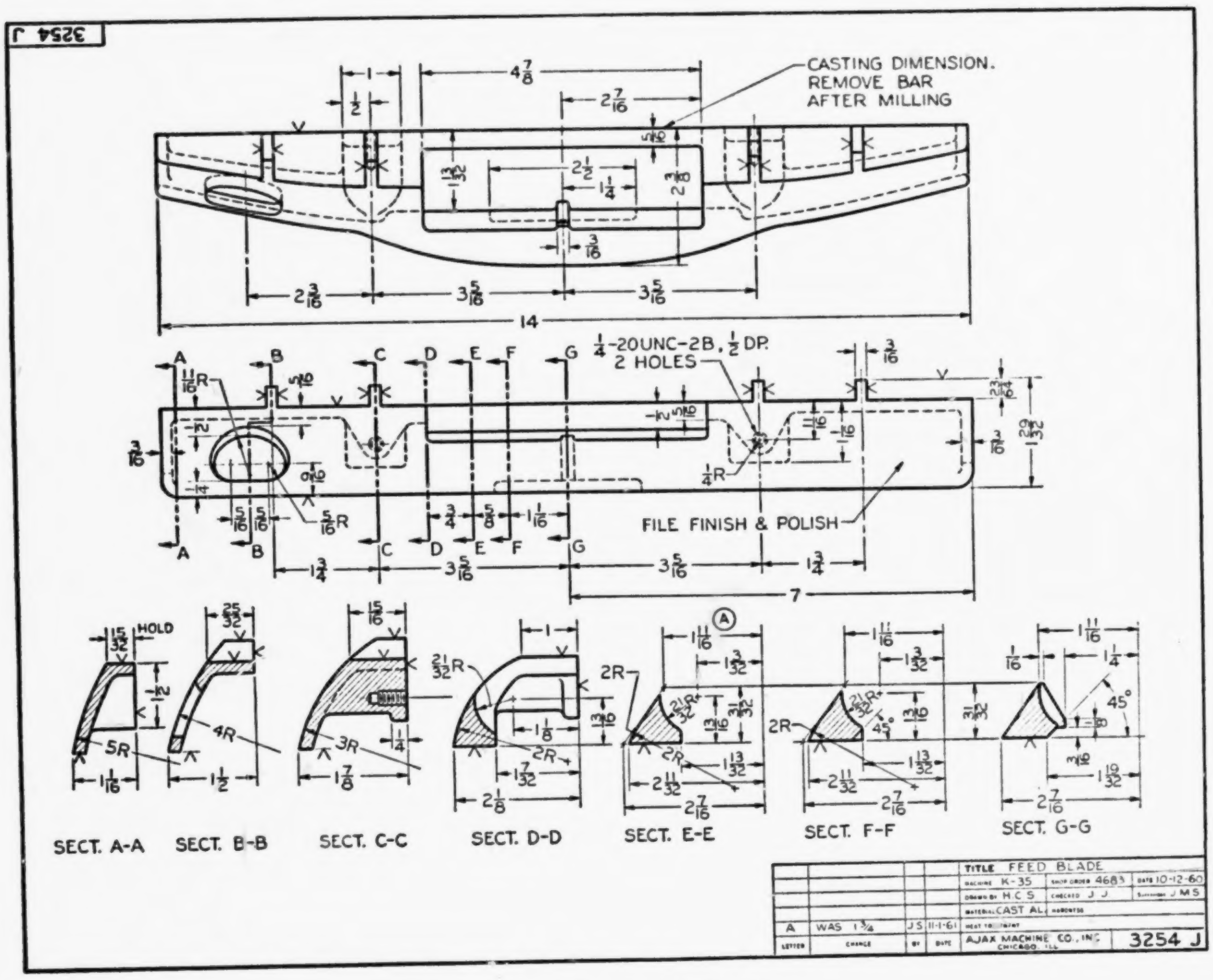
Removed Sections

Where it is not desirable to place sections on views due to crowded detail or the need for dimensioning space or additional detail, removed sections can be used (figure 5).

Removed sections provide additional description of form away from the original view area. As in figure 5 where several removed sections are drawn, they should be located at the bottom of the page on which the other views occur. References by means of letters at the cutting planes and section titles must be included, indicating a definite view from one point to another.

In cases where removed sections are linked directly to their derived position on the view (figure 6), as by means of center lines, no written reference need be provided.

In any case, removed sections should not be drawn in line with the standard arrangement of views.



3254 J
CASTING DIMENSION. REMOVE BAR AFTER MILLING
1/4-20UNC-2B, 1/2 DP. 2 HOLES
FILE FINISH & POLISH
HOLD
A
B
C
D
E
F
G
14
7
SECT. A-A
SECT. B-B
SECT. C-C
SECT. D-D
SECT. E-E
SECT. F-F
SECT. G-G
5R
4R
3R
2R
45°
TITLE FEED BLADE
MACHINE K-35
SHOP ORDER 4683
DATE 10-12-60
DRAWN BY H.C.S
CHECKED J J
SUPERVISOR J M S
MATERIAL CAST AL.
HARDNESS
HEAT TREATMENT
A
WAS 1 3/4
J S
11-1-61
LETTER
CHANGE
BY
DATE
AJAX MACHINE CO., INC. CHICAGO, ILL.
3254 J

Figure 5. **Removed Sections.**

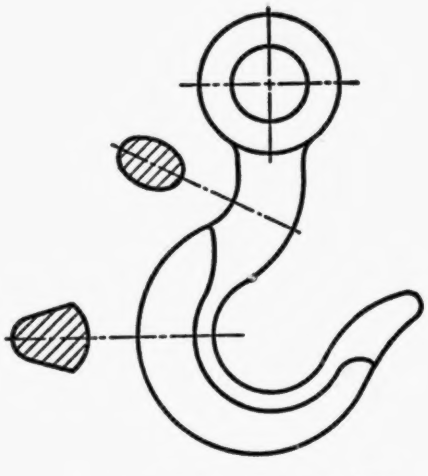
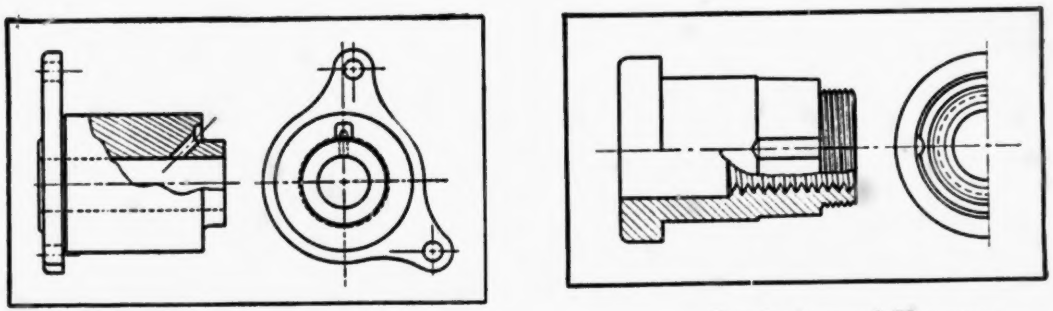


Figure 6.

Removed Sections

Broken Sections



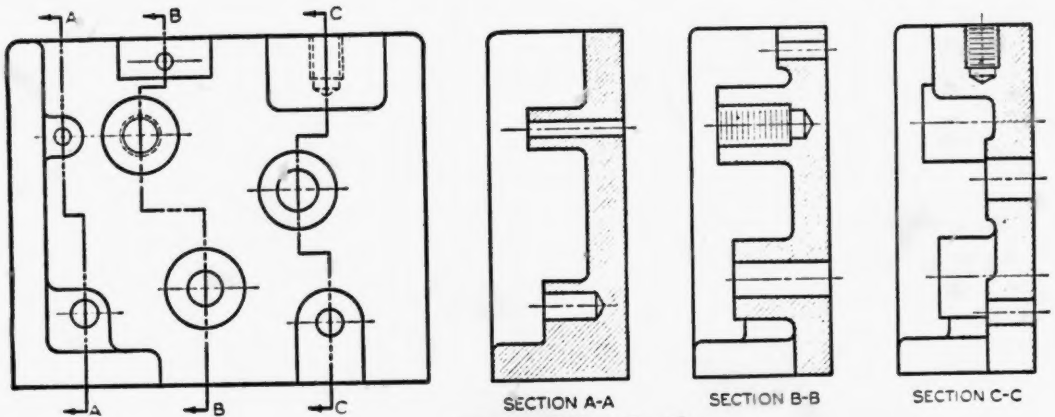
Broken-out Section. **Break Around Keyway.**

Figure 7.

In areas of views where only small portions of hidden features require additional visual or dimensional description, "broken out" sections may be used.

Adjacent features are preserved by "breaking out" around them. The break line is drawn as an object line to clearly outline the sectional area. Break lines may be used in combination with center lines to limit the section where necessary.

Multiple Sections



Three Offset Sections.

Figure 8.

In some cases it may be necessary to describe features of objects in several locations all parallel to a single plane of projection (figure 8).

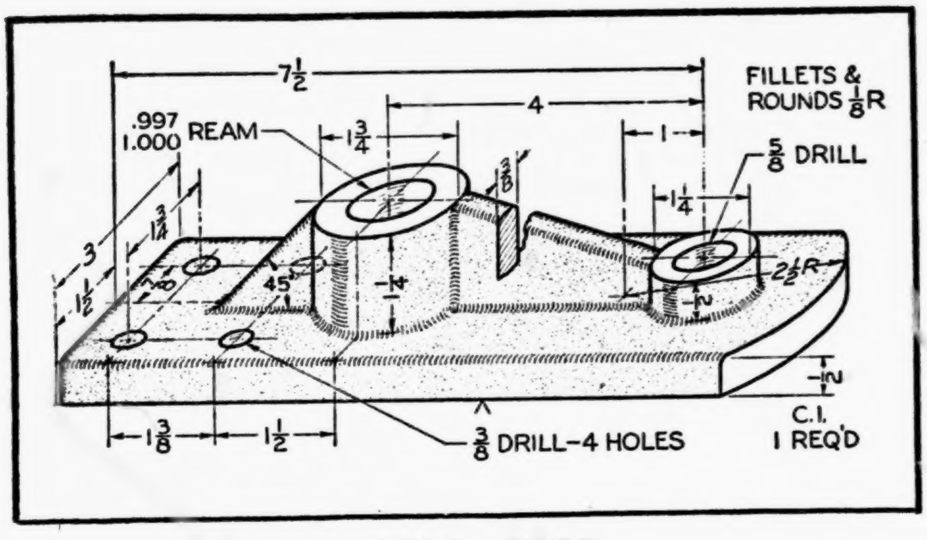
Multiple sections are drawn in line, replacing the regular view of the object in question, to describe details at the various points indicated by the cutting planes. The separate sections are labeled by their respective titles, and lettered references are given at the ends of each corresponding cutting plane. Only capital letters are used for this purpose.

Keep in mind the fact that no hidden lines are drawn.

ASSIGNMENT:

Problems 1 - 7 are to be drawn on size B paper using the working drawing title block. Use all previously discussed working drawing techniques.

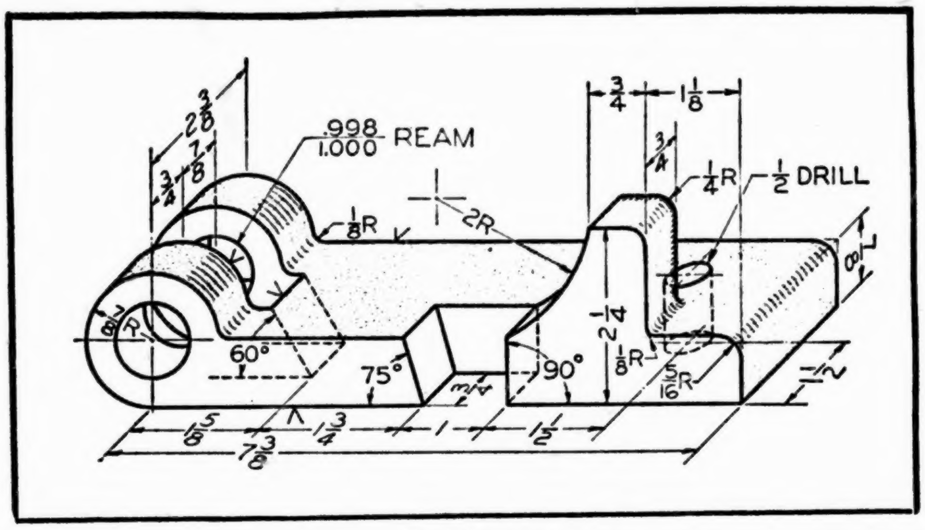
Problems 1-5 - require only front and top views. Show required sections on problems 3-5.
Problem 1 - should show partial revolved section at area of break.
Problem 2 - requires a broken section to show the hidden 60° angle.
Problem 6 - multiple sections should be placed adjacent to the top view at the right side position.
Problem 7 - requires an interchange of views. Study requirements carefully.



STOP BASE

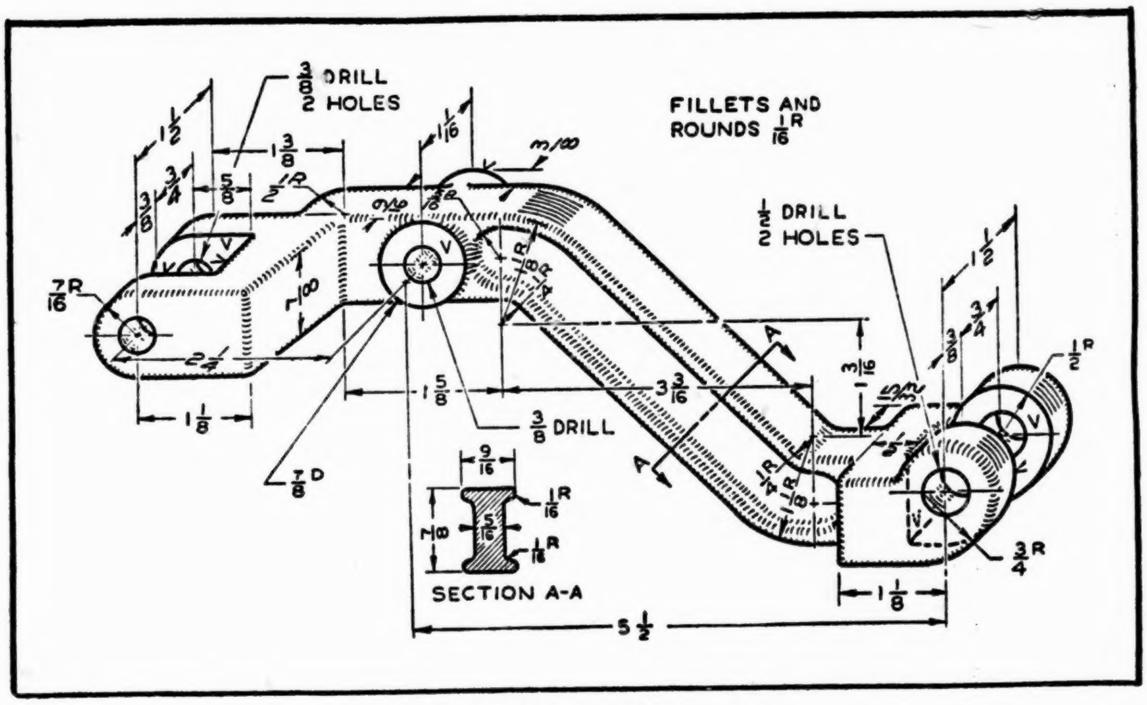
Problem 1.

Figure 2.



.998/1.000 REAM
1/2 DRILL
2R
1/8R
1/4R
60°
75°
90°
SECTION A-A

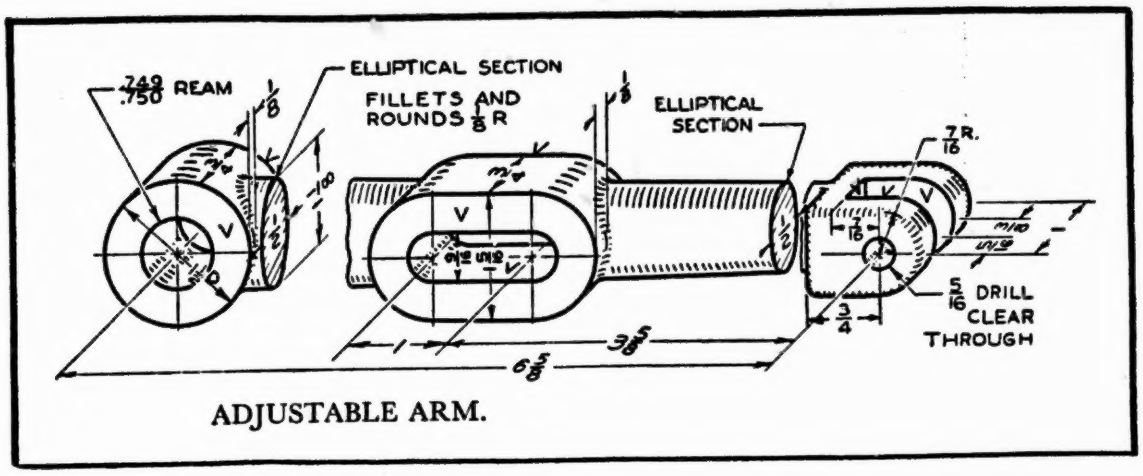
HINGE BASE



3/8 DRILL 2 HOLES
FILLETS AND ROUNDS 1/16 R
1/2 DRILL 2 HOLES
3/8 DRILL
7/8 D
SECTION A-A
5 1/2

LIFTING ARM

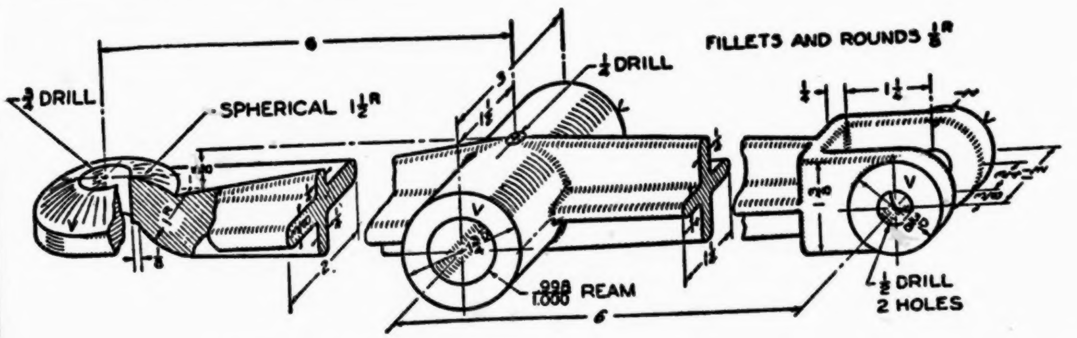
Figure 3.



.749/.750 REAM
ELLIPTICAL SECTION
FILLETS AND ROUNDS 1/8 R
ELLIPTICAL SECTION
7/16 R.
5/16 DRILL CLEAR THROUGH
6 5/8
3 5/8

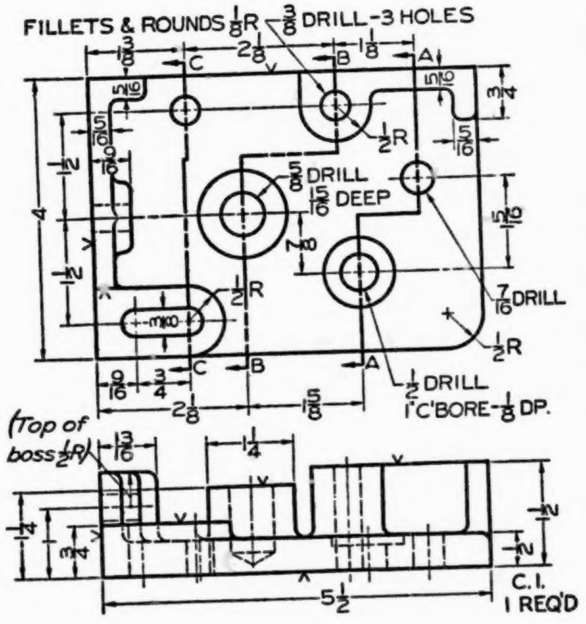
ADJUSTABLE ARM.

Figure 4.


$\frac{3}{8}$ DRILL
SPHERICAL $1\frac{1}{2}$R
6
3
$\frac{1}{2}$ DRILL
FILLETS AND ROUNDS $\frac{1}{8}$R
$1\frac{1}{2}$
$\frac{.998}{1.000}$ REAM
6
$\frac{1}{2}$ DRILL
2 HOLES
V

ROCKER ARM.

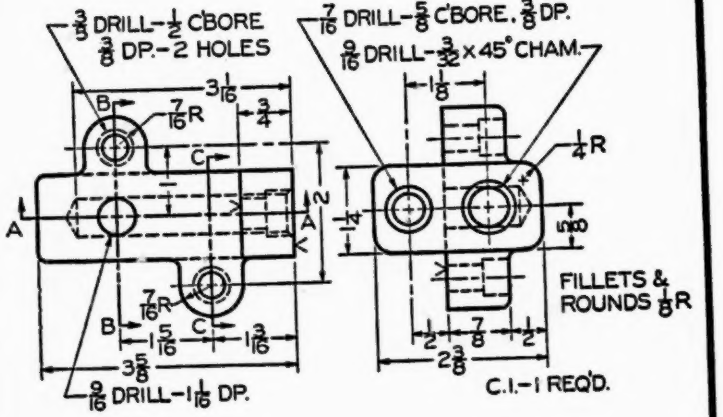
Figure 5.


FILLETS & ROUNDS $\frac{1}{8}$R
$\frac{3}{8}$ DRILL-3 HOLES
$\frac{5}{8}$ DRILL
$\frac{15}{16}$ DEEP
$\frac{7}{16}$ DRILL
$\frac{1}{2}$R
$\frac{1}{2}$ DRILL
1" C'BORE-$\frac{1}{8}$ DP.
(Top of boss $\frac{1}{2}$R)
$5\frac{1}{2}$
4
$2\frac{3}{8}$
$1\frac{5}{8}$
A
B
C
C.I.
1 REQ'D

Given: Front and Top views.
Req'd: Front, Top, and Sec's A-A, B-B, and C-C. Show all visible lines

Figure 6.

ADJUSTER BASE


$\frac{3}{8}$ DRILL-$\frac{1}{2}$ C'BORE
$\frac{3}{8}$ DP.-2 HOLES
$\frac{7}{16}$ DRILL-$\frac{5}{8}$ C'BORE. $\frac{3}{8}$ DP.
$\frac{9}{16}$ DRILL-$\frac{3}{32}$ x 45° CHAM.
$3\frac{1}{16}$
$\frac{7}{16}$R
$\frac{1}{4}$R
$3\frac{5}{8}$
$2\frac{3}{8}$
$\frac{9}{16}$ DRILL-$1\frac{1}{16}$ DP.
FILLETS & ROUNDS $\frac{1}{8}$R
C.I.-1 REQ'D.
A
B
C

Given: Front and R. Side views.
Req'd: Take Front as new Top; then add R. Side view, Front in full Section A-A, and Sections B-B and C-C

Figure 7.

BRACKET

Assembly Sections

Lesson 4

OBJECTIVES:

1. To introduce techniques of sections peculiar to assembly drawings.
2. To review the application of assembly drawings to production work.

REFERENCES:

1. Chapter 14, TECHNICAL DRAWING, Giesecke, Mitchell, and Spencer.
2. Chapter 8, MECHANICAL DRAWING, French and Svensen.

INFORMATION:

In Unit IV, Lesson 5, the basic relationship of assembly drawings to working detail drawings was introduced. Installation or outline assemblies were discussed in addition to working drawing assemblies. (Review this material if necessary.)

Sections of parts in assembly greatly simplify the understanding of parts relationships in total machines or other mechanical devices. Whenever two or more parts are shown assembled in section, special techniques of drawing apply.

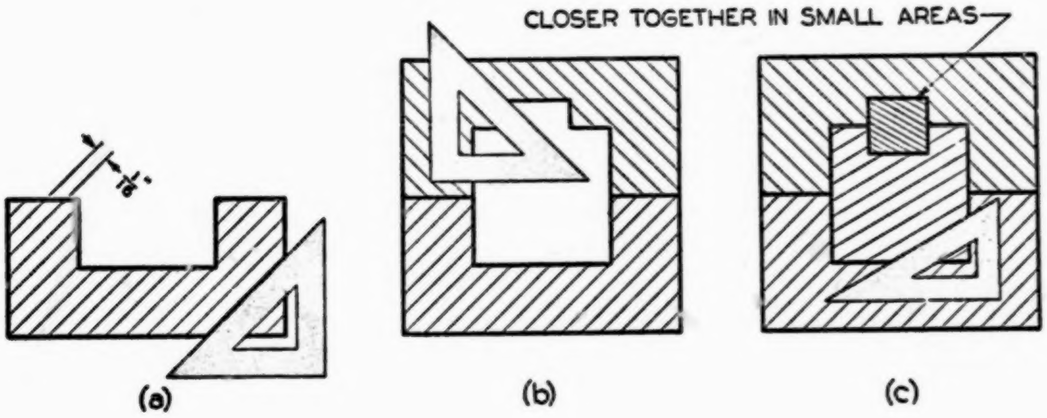


Figure 1.

Figure 1 denotes the basic structure of section lines as they should appear in assembly situations. Notice that "general purpose" section lines are used for most assembly applications. As you will recall, section lines are generally placed $\frac{3}{32}$" apart and are drawn at a 45° angle. In assembly drawing, however, both the spacing and the drawing angle for the section lines may be changed to suit the situation.

Spacing may be varied from $\frac{1}{16}$" to $\frac{1}{8}$" between lines, depending for the most part on the relative size of the sectional area. Smaller areas generally require closer spacing of lines. Practice spacing lines "by eye", exercising care to keep the spaces uniform.

The drawing angle for the lines should generally be maintained at 45° unless some advantage is gained by changing the angle. The use of lines running in opposite directions at 45° should be your first choice to differentiate between parts. Thereafter, an angle of 30° or 60° in either direction may be used. Unless there are more than two parts located closely, a change of angle will not be required. Remember that the same direction of lines should be maintained on any one part even if the sectional areas for that part are isolated. Some difference should be visible in the section lines used on all separate parts. For drawing balance, the same distance between lines should be used in all sectional areas of relatively equal size.

One precaution is necessary where section lines in adjacent parts intersect a common object line. At these points, the lines should be staggered to further prevent confusion between parts.

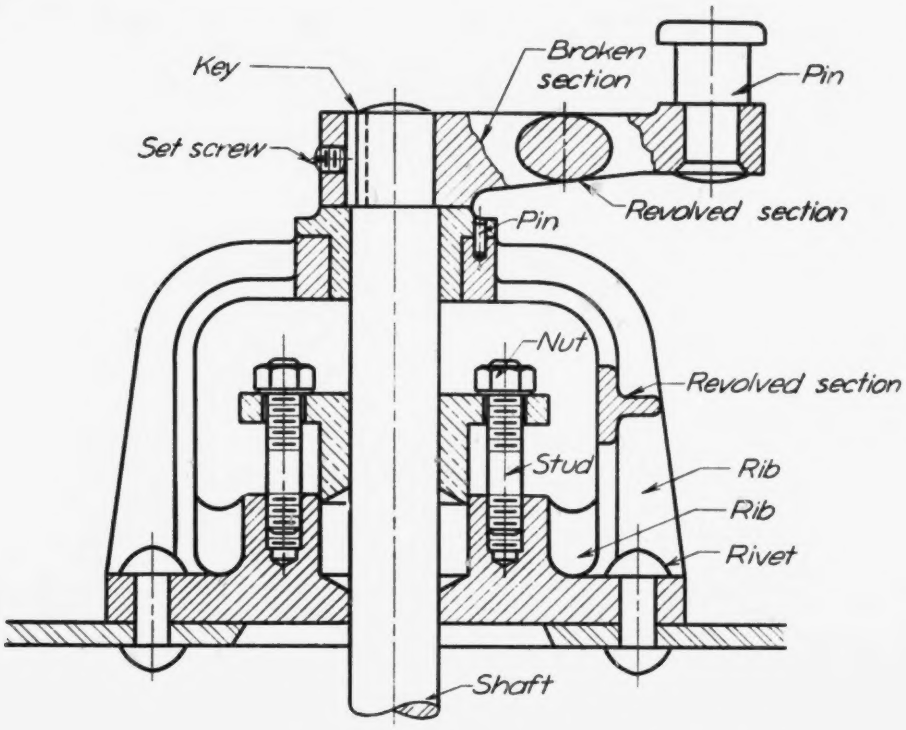
BE SURE THAT SECTION LINES DO NOT RUN PARALLEL OR NEAR PARALLEL TO ANY OBJECT LINES.

Solid Forms in Sections

The main purpose of sections, that of showing interior details clearly, should be kept in mind. Solid forms such as bolts, shafts, pins, rivets, etc., are never shown in section on assembly drawings, as they have no internal detail for the most part. In special cases where internal detail exists, such as the intersection of a shaft and key, broken sections of such parts may be used.

Figure 2 shows one example of solid parts included in assembly drawings. Notice that showing the exterior detail of shafts and bolts greatly increases the effectiveness of the assembly in describing parts relationships. Notice also that symbolic sectioning is used to indicate various material applications such as steel for the bottom plate and bronze for the upper shaft bushing.

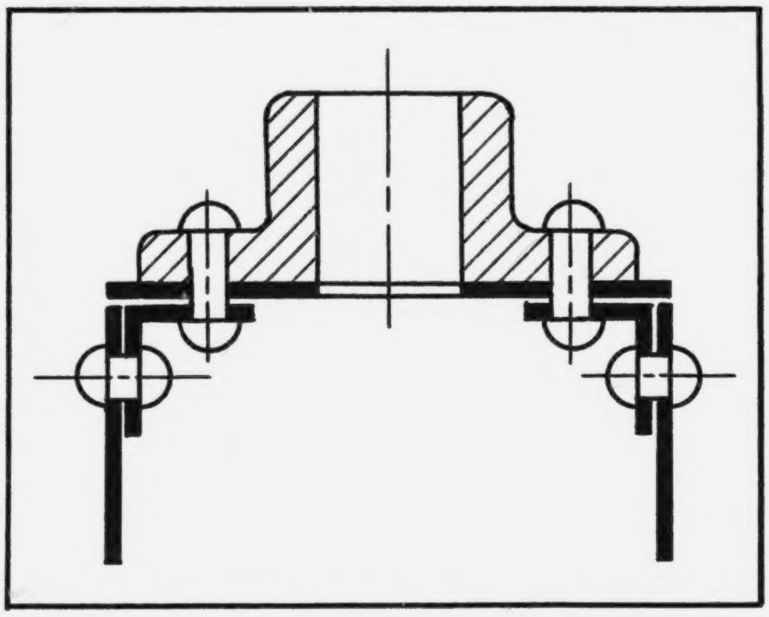
SYMBOLIC SECTIONING MAY BE USED IN ADDITION TO LINE ANGLE AND SPACING CHANGES TO FURTHER CLARIFY THE LIMITS OF VARIOUS PARTS IN ASSEMBLY.


Key
Set screw
Broken section
Pin
Revolved section
Pin
Nut
Revolved section
Stud
Rib
Rib
Rivet
Shaft

Bolts, shafts, and so forth, on sectional views.

Figure 2.

Thin Parts in Section



SECTIONING THIN PARTS

Figure 3.

Figure 3 shows the use of solid "blacked-in" areas for thin parts shown in section. Sheet metal, gaskets, etc., cannot be effectively illustrated by the use of section lines due to their size. When two or more adjacent thin parts are sectioned, a small "white" area should be left between them to show object limits.

Remember that notes or identification numbers indicating a descriptive reference to each part must be included in order to identify material requirements on assembly drawings.

When it is necessary for you to draw assemblies, review the basic techniques with your instructor and seek additional information from texts and other reference materials.

QUESTIONS:

1. What is the difference between a working drawing assembly and an outline assembly?
2. Where a common object line is involved between parts in section, what precaution must be taken in drawing section lines?
3. What angle should be used for section line assembly drawings as a first choice? What other angles may be used when necessary?
4. What is done concerning solid forms in section?
5. When using "symbolic sectioning", why is it still necessary to note the use of materials on drawings?

UNIT V - SECTIONS AND RELATED CONVENTIONS

Special Sections

Lesson 5

OBJECTIVES:

1. To introduce partial sections.
2. To explain the application of conventional "breaks" as they apply to sections.
3. To explain applications of auxiliary sections.
4. To briefly describe outline sections.

REFERENCES:

1. Chapter 7 and 8, TECHNICAL DRAWING, Giesecke, Mitchell, and Spencer.
2. Chapter 8, MECHANICAL DRAWING, French and Svensen.

INFORMATION:

There are many applications of section drawings in conjunction with other views of objects in providing additional parts description. The drawing of separate sectional views of objects in detail or assembly situations, or the drawing of a complete sectional portion on existing views, is sometimes not considered "economically sound" drafting practice. In industry, time is often the important factor in the production of working drawings. Therefore, the draftsman should apply his knowledge concerning "shortcut" methods available within the confines of accepted drawing procedure. This should, however, be done only when sufficient skill is attained to intelligently apply these practices.

The following special applications of sections show how the necessity for drawing additional views of objects may be eliminated through a functional knowledge of their use.

Partial Sections

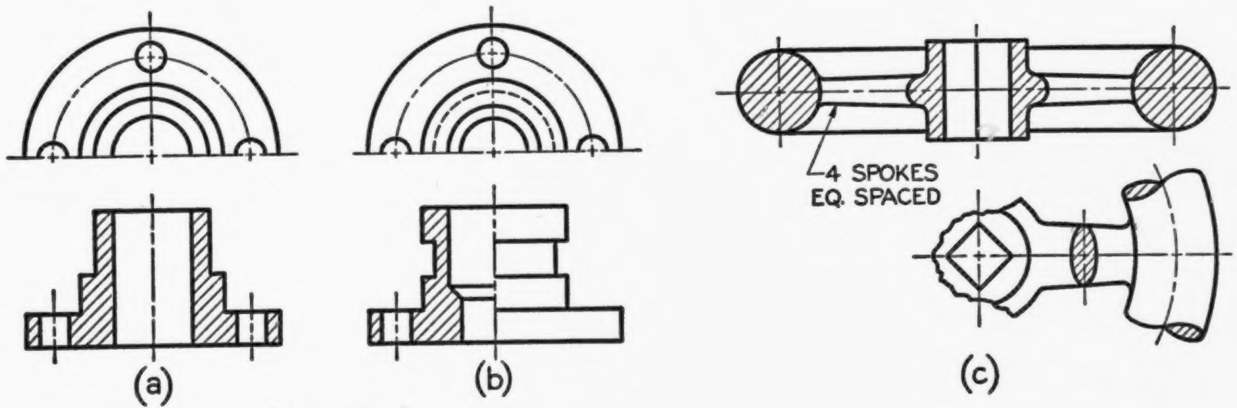


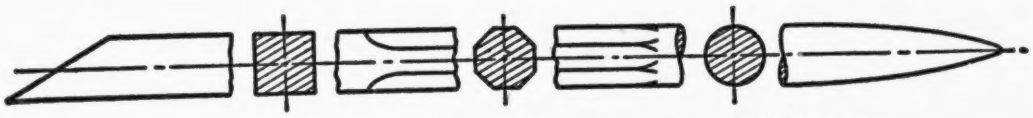
Figure 1.

As in the case with regular views of objects shown in part, partial section views are used when the entire view is not necessary for various possible reasons. For example, it may not be necessary to show entire views of a handwheel (figure 1c) in order to provide description of spoke placement and form.

The regular views of the object may also be shown in part with adjacent section views (figure 1a-b). In these situations the back portion of the object is shown in keeping with the imaginary removal of the front portion to attain the desired section. Note the elimination of cutting planes in drawing these views.

Conventional Breaks

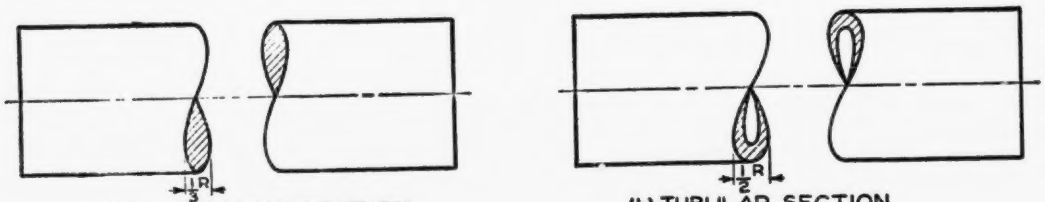
In many instances, especially where elongated objects are shown or not all of an entire view is necessary for adequate description, conventional "breaks" may be used.



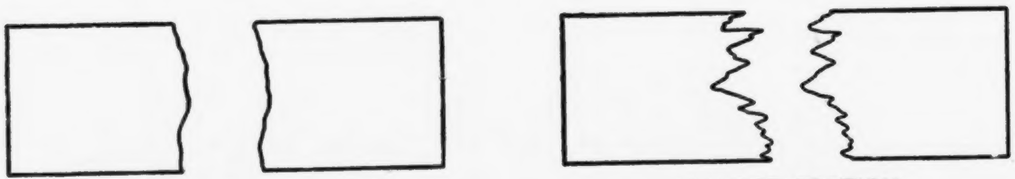
Conventional Breaks Used with Revolved Sections.

Figure 2.

For the purpose of providing a space for sectional views such as the incorporation of revolved sections (figure 2), a central portion of objects may be omitted by using break lines designed for each particular object form.



(a) SOLID ROUND SECTION (b) TUBULAR SECTION



(c) RECTANGULAR SECTION (d) WOOD SECTION

Figure 3. Break Lines for Geometric Forms

Figure 3 shows the basic form of "break lines" used for various geometric forms. On round (a) or tubular (b) objects, specially constructed areas are used to offset the break. Section lines are placed on the exposed portions of the "broken" ends of these forms.

For broken sections of rectangular objects, a regular break line limits the partial view (figure 3e). Special sharp offsets are used for break lines on sections of wood or composition materials (d).

Conventional breaks may also be utilized in the above cases merely to eliminate portions of exceptionally long object views which would ordinarily not fit on the page. In these cases (figure 3) both ends of the object must be drawn for reference purposes, and any amount of the central portion may be eliminated. No additional sections need be included.

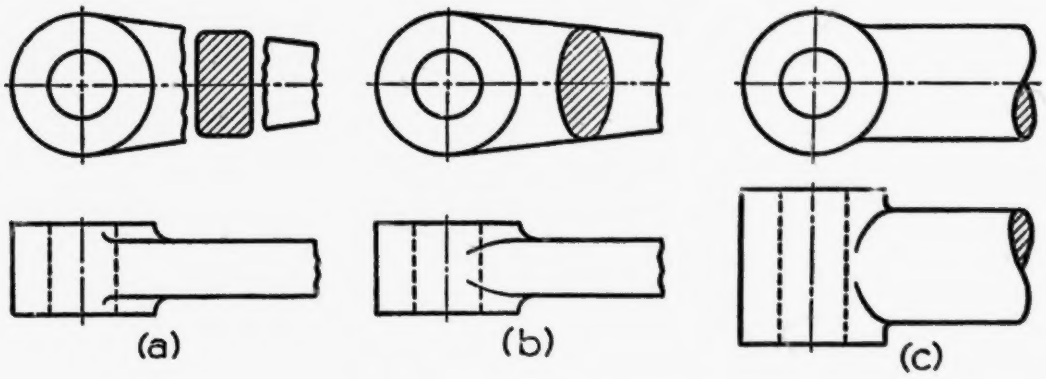
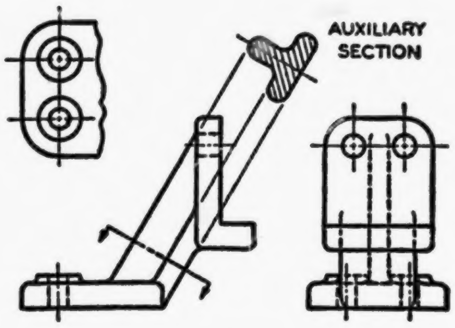


Figure 4. Break Line Applications

Figure 4a-c further illustrates the applications of the various break lines in specialized situations.

Auxiliary Sections

Auxiliary views of objects may sometimes be shown as sections (figure 5) for convenience in describing object form. The principles behind the drawing of the section and its purpose remain the same as before, except that the section view is placed in an "auxiliary" position.



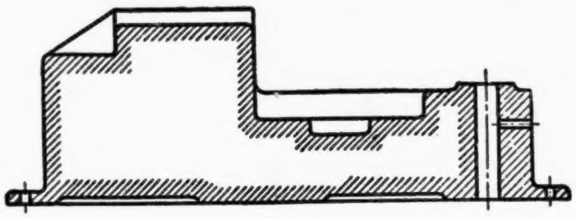
Auxiliary Section.

Figure 5.

Outline Sections

Where large areas are shown in section (figure 6), it is not necessary to draw the section lines fully across the view. Merely draw section lines adjacent to the object outline, terminating them at a consistant length around the entire view. Smaller areas on the same "section" may be fully lined.

This procedure is mainly a timesaving device. Full section lines should always be drawn where internal details are shown.



Outline Section.

Figure 6.

ASSIGNMENT:

Learn the specific applications for the methods outlined and apply them in your present drawing assignments where necessary.

The use of assembly sectioning techniques will be realized with the final drawing project in this course.

Review all materials in this and other lessons as found necessary. Use reference materials often to supplement your knowledge of drawing techniques.

1. A PARTIAL REVOLVED SECTION IS REQUIRED IN PROBLEM 1 included with the assignment for Unit V, Lesson 3.
2. Use auxiliary sections where possible for the problems listed in connection with Unit III, Lesson 3.
3. Auxiliary sections may also be used for drawings made of the object shown in figures 513 and 515 on pages 254-255 of TECHNICAL DRAWING, 4th edition.

UNIT VI - ISOMETRIC DRAWING

Principles of Projection

Lesson 1

OBJECTIVES:

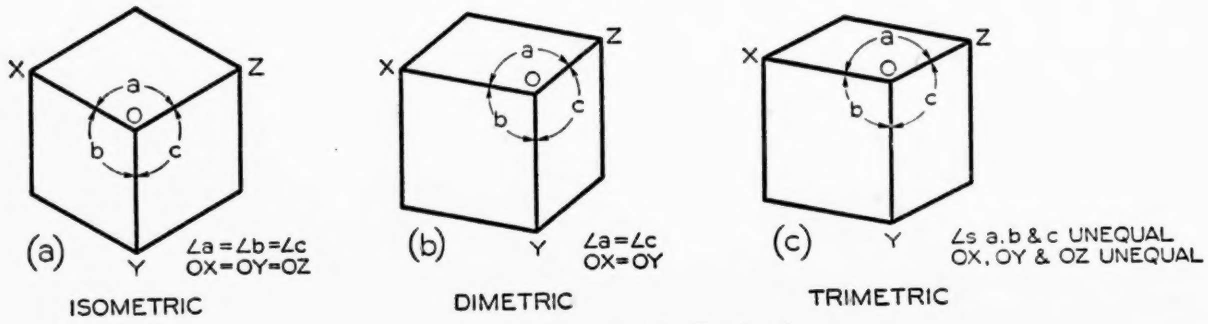
1. To define isometric drawing as related to orthographic projection.
2. To describe theory of projection.
3. To describe combined planes of projection.
4. To describe "normal" surfaces.

REFERENCES:

1. Chapter 15, TECHNICAL DRAWING, Giesecke, Mitchell, and Spencer.
2. Chapter 14, MECHANICAL DRAWING, French and Svensen.

INFORMATION:

Isometric drawing is the form of pictorial drawing most closely related to orthographic projection. Isometric drawing falls under the overall category of axonometric projection which also includes dimetric and trimetric projections (figure 1).



Axonometric Projections.

Figure 1.

In axonometric projection, as in multiview projection, the observer is considered to be at infinity in relationship to the object; and the projectors are again parallel to each other and are perpendicular to the plane of projection. The only difference is that the object is inclined in respect to the plane of projection. The principal edges and surfaces of the object being inclined to the plane of projection results in the changing of the sizes of angles, general proportions of the object, and the length of lines. There are an infinite number of possible positions in respect to the plane of projection at which the object may be placed.

Foreshortening of Lines

As any line is set at an angle to the plane of projection, visual "foreshortening" of its length will occur. The greater the angle, the greater the foreshortening that will occur. By setting the object at various angles to the plane of projection, varying degrees of "foreshortening" will occur on the several axes of the object (figure 1).

Note. SEE TEXT REFERENCES FOR DESCRIPTION OF DIMETRIC AND TRIMETRIC PROJECTION TECHNIQUES.

Isometric Projection

In order to produce an axonometric projection, measurements must be made parallel to the axes of projection.

In isometric drawing, a position of reference for the object is assumed that will display an equal portion of each surface. Therefore, each axis of the object will be equally "foreshortened." The term "isometric" means "equal measure." As a result of the foreshortening process, a true isometric drawing would be drawn using lines equal to approximately 80% of their true size.

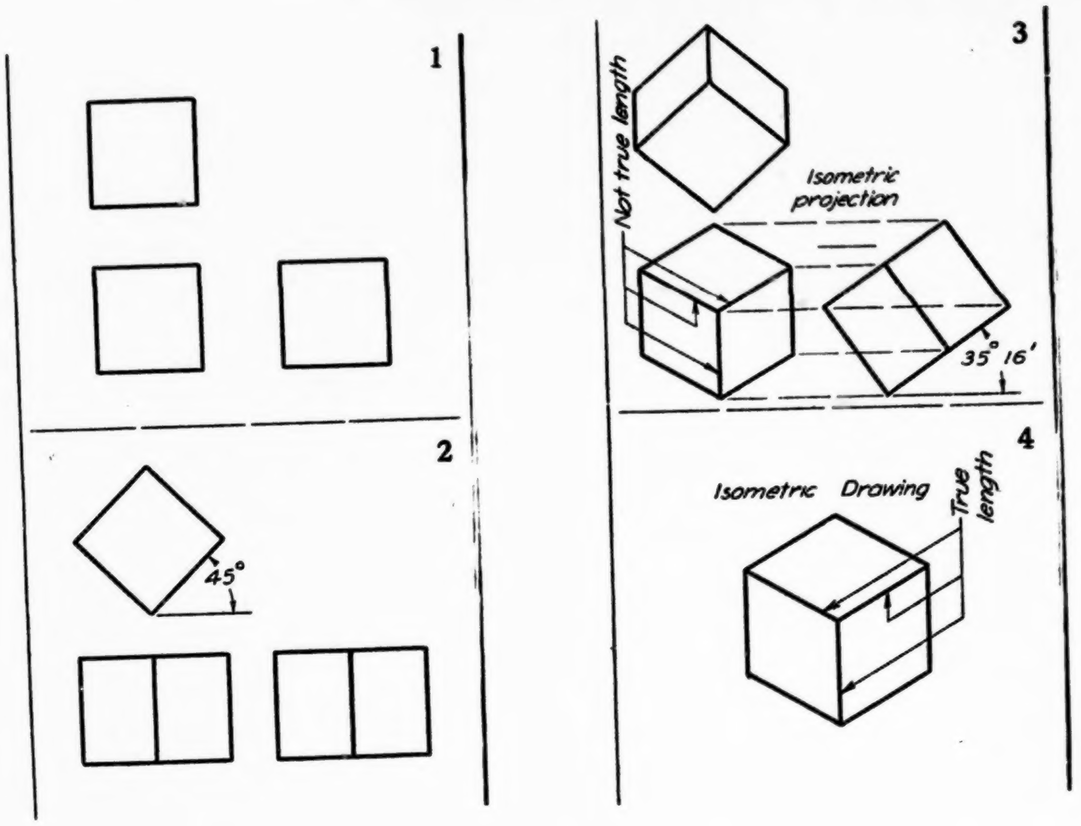


Figure 2. Isometric Projection

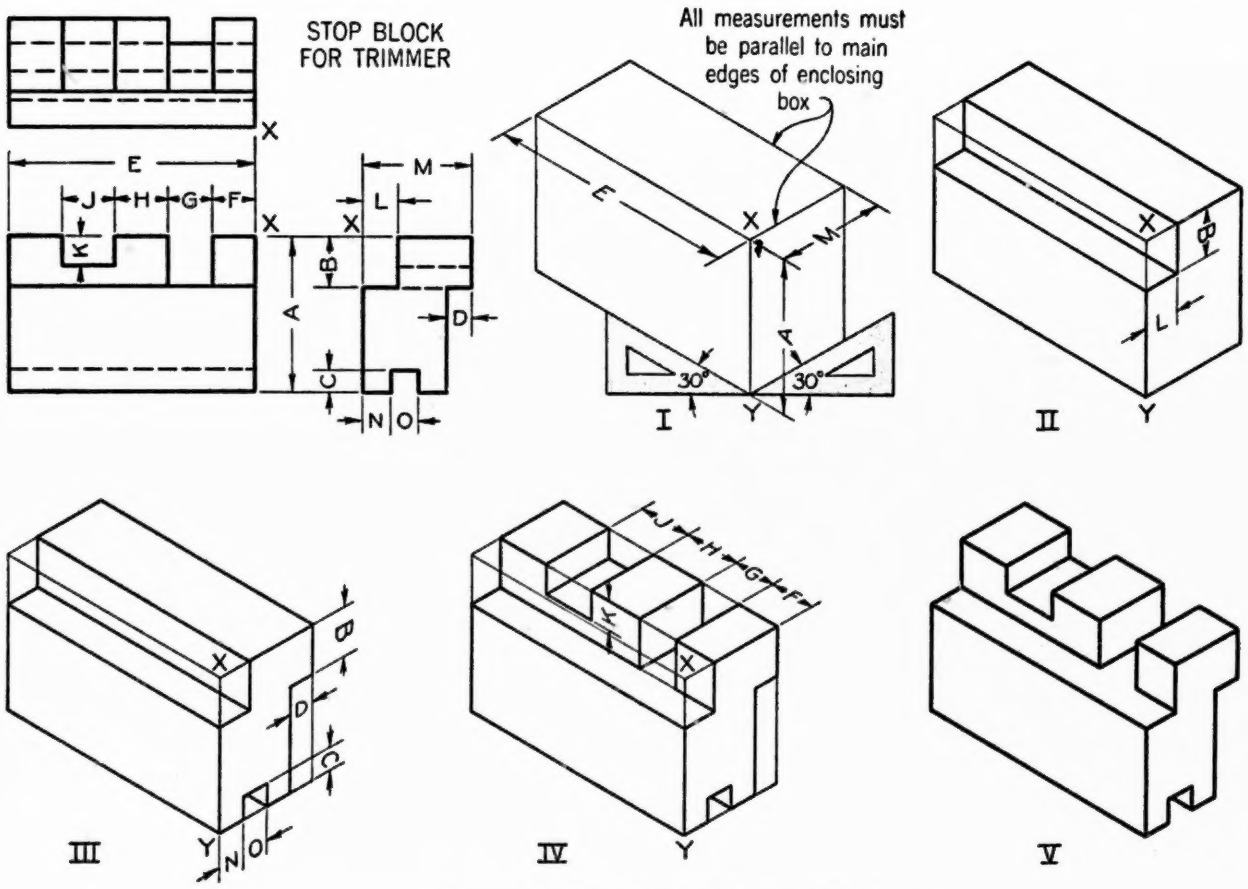
For convenience, isometric drawings show the true length of each line projected on the three axes, figure 2(4), resulting in a pictorial view appearing to be on a somewhat larger scale than the regular multiview projection. Bear in mind that isometric projection is actually a form of orthographic projection.

Theory of Projection

The three regular views of an object are directly related to their isometric projection, figure 2(1). By revolving the object on a vertical axis to expose an equal portion of both the front and right sides (2) and then tilting the object forward at the correct angle (35° 16'), the front view will show the three "fores" of the object projected equally in shape and size (3). The three axes of the object will then be at equal angles (120°) in respect to one another (figure 1a).

Isometric Planes

In isometric drawing, as in regular multiview projection, we will refer to the regular surfaces of the object as the three planes of projection or more simply, isometric planes.


STOP BLOCK FOR TRIMMER
All measurements must be parallel to main edges of enclosing box
E
J
H
G
F
K
X
M
L
B
A
D
C
N
O
Y
30°
30°
I
II
III
IV
V

Isometric Drawing of Normal Surfaces.

Figure 3.

Since the angles between the axes of the object (width, depth, height) are equally spaced at 120°, it is necessary to offset the horizontal axes 30° from the horizontal position of the page (figure 3) to make the isometric drawing. Therefore, the 30-60° triangle will be used for the projection of all normal surfaces in isometric drawing.

To make the isometric drawing, first project guide lines vertically at the position of the right front corner and secondly, horizontally (30°) to the left and right of the vertical guide, figure 3(1).

Block in the total area of the isometric drawing by measuring the distances equal to the edges of the object in each of the three views along the corresponding axes. Enclose the area by drawing guide lines parallel to each of the three axes at the measured limits.

Spacing an Isometric Drawing

Since an enclosing "box" must be drawn limiting the overall size of the object when beginning an isometric drawing, it will be found convenient to estimate the final size of the finished drawing in order to approximately "center" it on the drawing page.

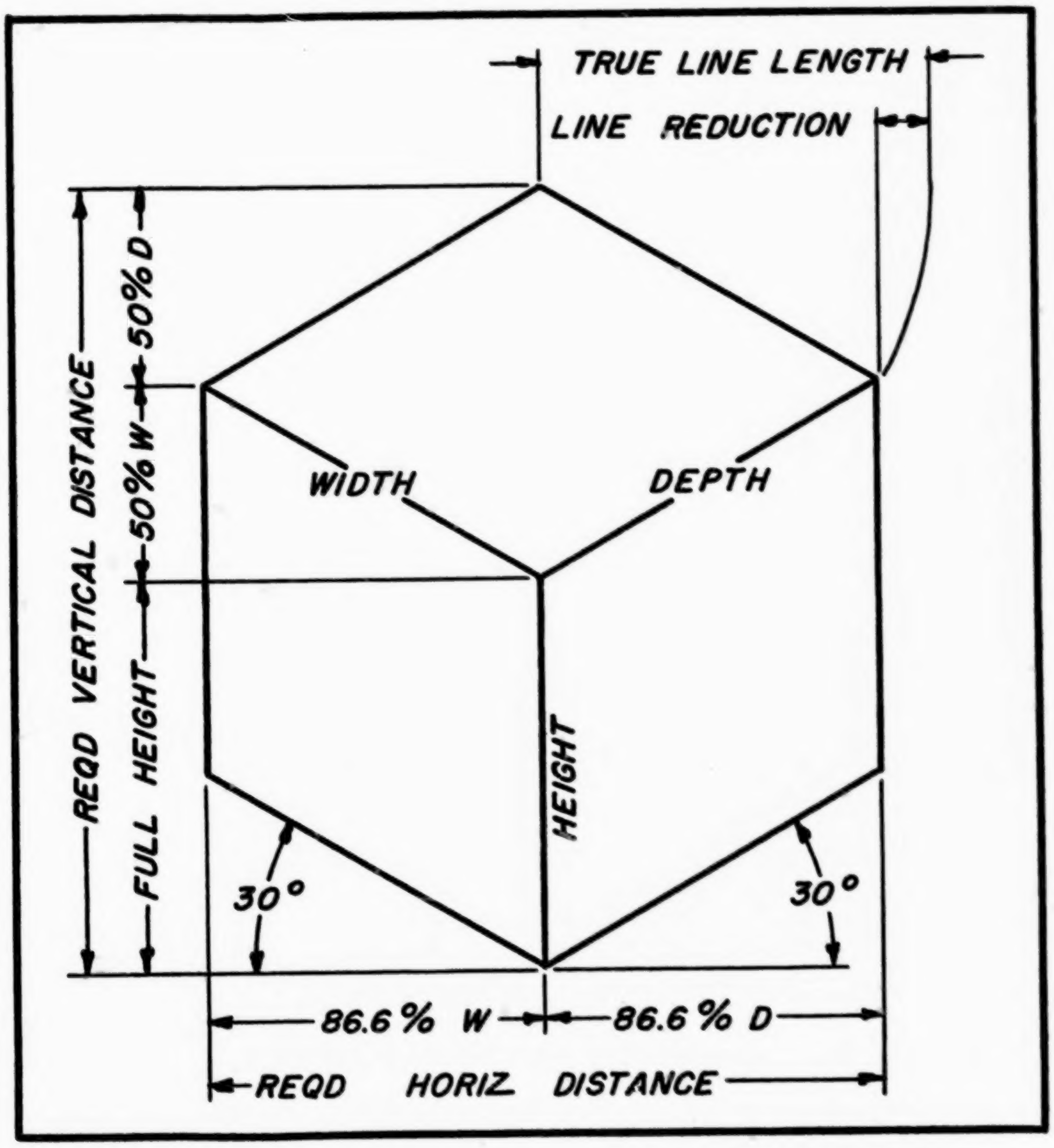
An approximate spacing for isometric drawings can be attained by finding the total horizontal and vertical distance required on the page, applying the following steps:

HORIZONTAL SIZE

1. Add the width of the front view and the depth of the right side view together.
2. Since the space requirement is "foreshortened" by the 30° angle of projection, multiply the figure from step #1 by .866. Therefore, the total horizontal distance required for the drawing will be approximately 86.6% of the combined width and depth of the object.

VERTICAL SPACING

3. Since portions of the true width and depth of the object, in addition to its full height, compose the vertical space occupied by the isometric drawing, all three dimensions must be considered.
4. To calculate the approximate vertical distance required, add together the height of the object and 50% of the width and depth. Therefore, the vertical space occupied by an isometric view will be equal to 50% of the total combined width and depth plus the full height of the object.


TRUE LINE LENGTH
LINE REDUCTION
REQD VERTICAL DISTANCE
FULL HEIGHT
50% W
50% D
WIDTH
DEPTH
HEIGHT
30°
30°
86.6 % W
86.6 % D
REQD HORIZ DISTANCE

SPACING OF ISOMETRIC DRAWINGS

Figure 4.

Note. *This method of spacing for instrument* drawing is only approximate. A reduction in the size of the finished view will be realized if the surfaces of the object are offset from the overall limits of the isometric planes originally blocked in. However, the maximum limits of the view, vertically and horizontally, are calculated by this means.

Locating the Starting Point

In order to locate the starting point or the position of the right front corner, place the vertical guide at a distance equal to .866 of the object depth from the right side of the total horizontal space calculated.

Projecting "Normal" Offset Surfaces

As mentioned before, "normal" surfaces in isometric drawing are those which are parallel to the isometric planes. In order to locate surfaces offset from the enclosing edges of "box", figure 3(I), transfer distances from the multiview drawing, placing them parallel to the corresponding isometric plane. Study figure 3, steps II, III, and IV. Finish the drawing (step V) by darkening all visible object lines.

Note. NO HIDDEN LINES ARE DRAWN ON ISOMETRIC VIEWS.

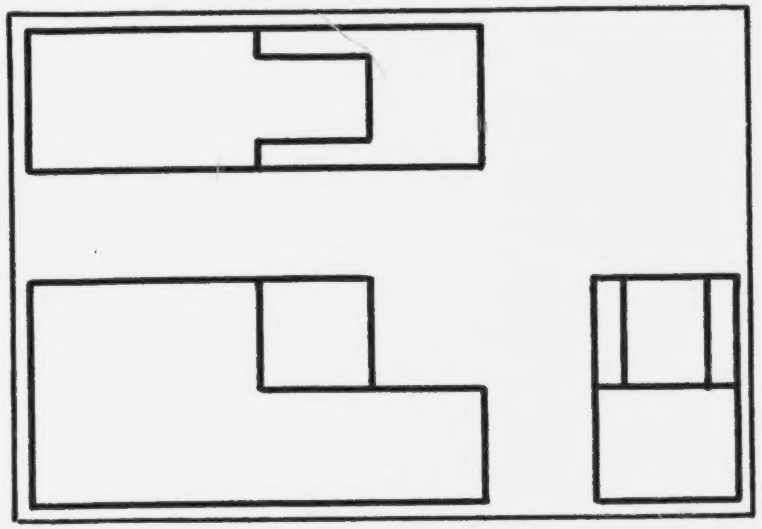
QUESTIONS:

1. What does the word "isometric" mean?
2. At what angle are horizontal axes projected?
3. Are all sides of the object equally "foreshortened"? If so, why?
4. What is meant by the term "isometric plane"?
5. What included angle results when projecting a representation of the 90° angle between isometric axes?

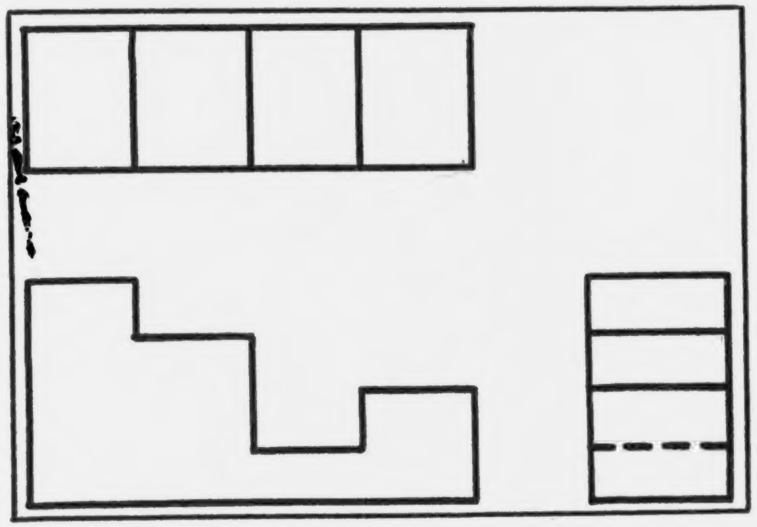
ASSIGNMENT:

Following the described procedures, make an isometric sketch of problems 1-4 on plain white paper. Keep the sketch proportionate to the overall features of the object. You do not have to measure the length of lines in your sketches. For problems 3 and 4 you must "visualize" the features of the missing top view.

For problem 5, make an isometric drawing of a $2\frac{1}{2}$" cube using instruments on plain white paper. Read lesson 4, Unit VI, and place fractional dimensions describing the width, depth, and height of the view. Use the simplified title block. Center the problem, and title it "CUBE."

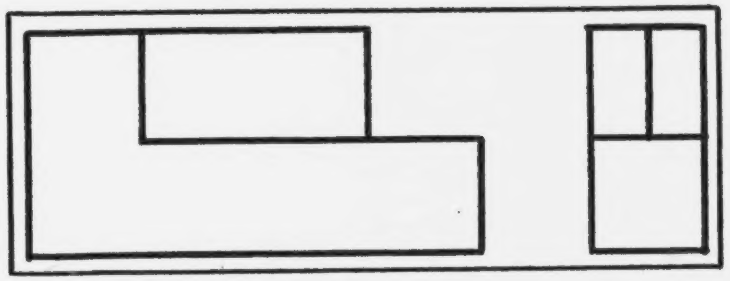


Problem 1.

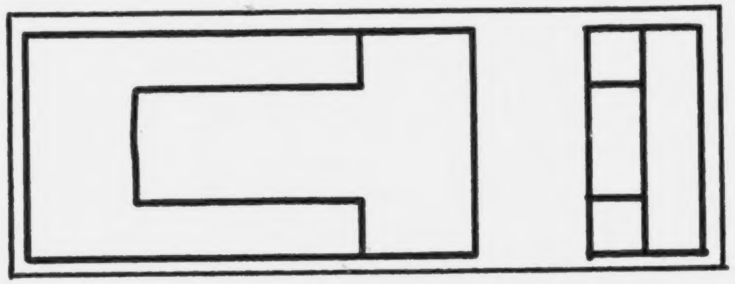


Problem 2.

(ALL FIGURES APPROX. 1/2 SCALE)



Problem 3.



Problem 4.

UNIT VI - ISOMETRIC DRAWING

Circles in Isometric

Lesson 2

OBJECTIVES:

1. To relate the "approximate four-center ellipse" method for representing circles parallel to isometric planes.
2. To apply this method to the drawing of holes and arcs in isometric drawing.

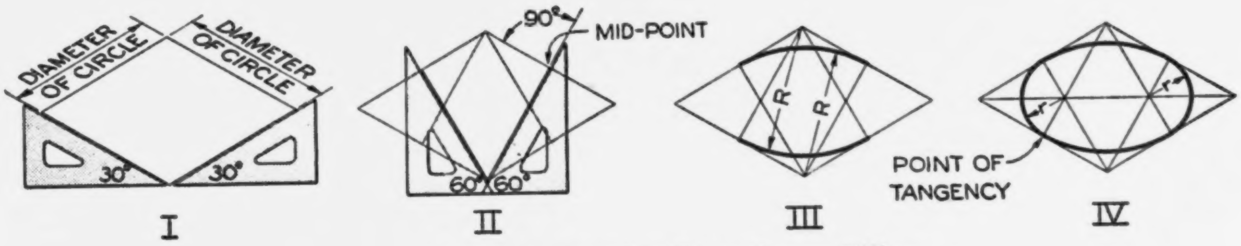
REFERENCES:

1. Chapter 15, TECHNICAL DRAWING, Giesecke, Mitchell, and Spencer.
2. Chapter 12, ENGINEERING DRAWING, Zozzora.

INFORMATION:

Quite often in the construction of isometric drawings it will be necessary to construct ellipses of circles to represent rounded corners or holes on the objects.

One method of representing arcs and circles in isometric drawing is by drawing a "four-center ellipse."



Steps in Drawing Four-Center Ellipse.

Figure 1.

Figure 1 shows the steps for constructing the "four-center ellipse." Construct a "square" in isometric whose sides are equal to the diameter of the circle (I). Erect perpendicular bisectors to each side of the square using the 30°-60° triangle (II). Draw two large arcs (R) from the corners of the square at which the bisectors intersect (III). Draw two small arcs (r) from the intersections of the bisectors within the "square"to complete the ellipse.

By adding the dimension of depth, the isometric ellipse can be used to represent either a shaft or hole.

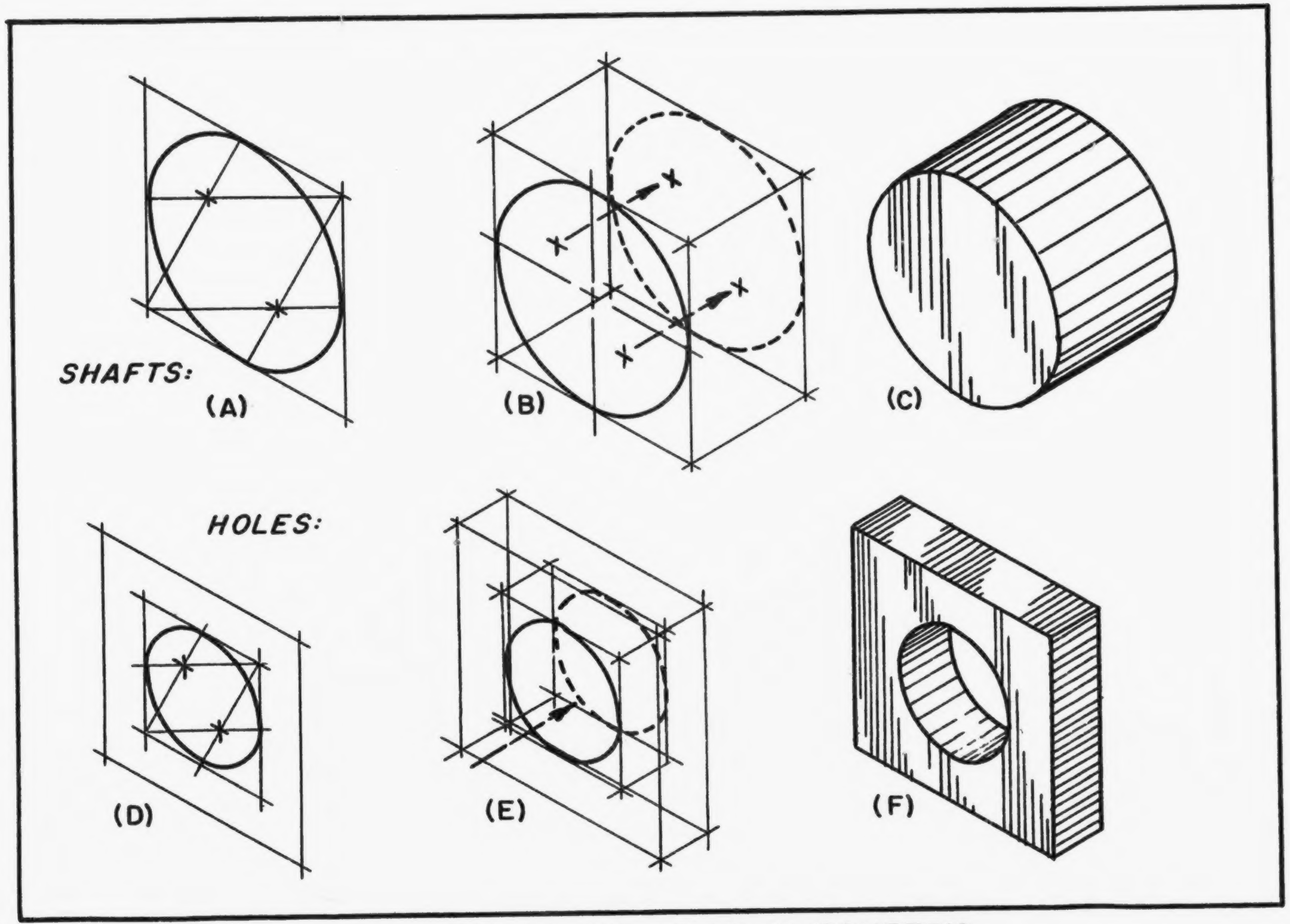

SHAFTS:
(A)
(B)
(C)
HOLES:
(D)
(E)
(F)

Figure 2. SHAFTS AND HOLES IN ISOMETRIC

Drawing a Cylinder

Figure 2 shows the original ellipse construction of the front face of the object (A). By transferring the positions of the four centers to the desired depth within the construction area (B), the same compass settings are used to construct the rear of the object, in this case representing a shaft (C).

Drawing a Hole

By drawing the isometric "square" within the confines of the original object guide lines at the desired location (D), an ellipse is constructed on the face of the object. Transferring centers to a point on the rear object plane, the ellipse is again constructed (E). Note that since hidden lines are not shown in isometric, only that portion of the ellipse exposed in the final representation of the hole (F) need be drawn.

Tapered Objects

To draw tapered objects (figure 3) the two different diameters are constructed at opposite ends of the object (step 1). The ellipses are aligned along the central axis of the object (step II), and object lines are drawn tangent to the ellipses to complete the object (final step). These final object lines are not parallel to the isometric planes.

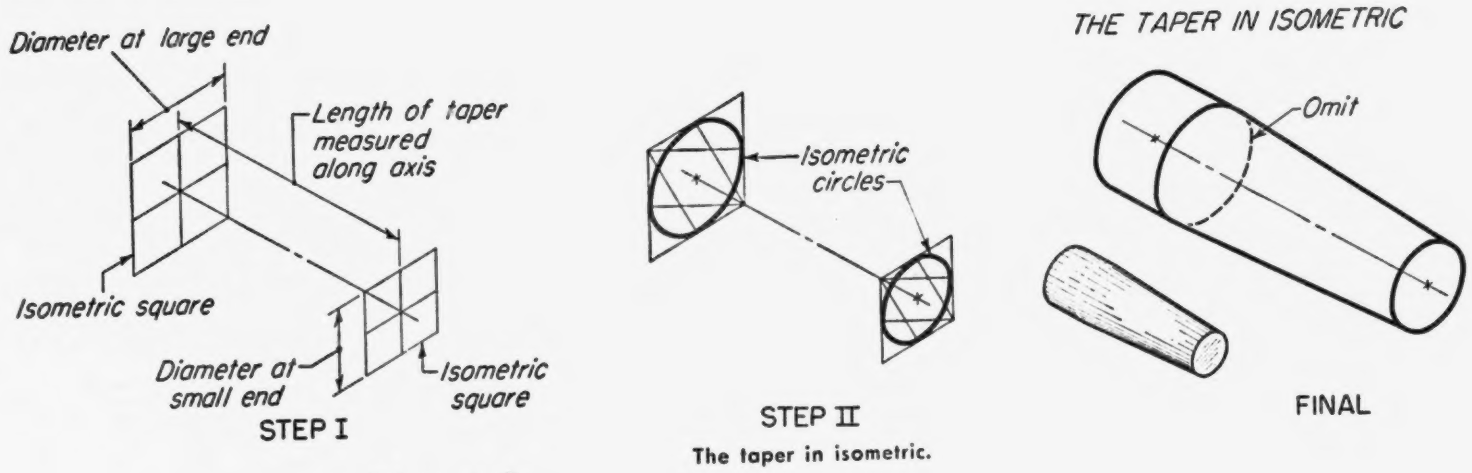

Diameter at large end
Length of taper measured along axis
Isometric square
Diameter at small end
Isometric square
STEP I
Isometric circles
STEP II
The taper in isometric.
THE TAPER IN ISOMETRIC
Omit
FINAL

Figure 3.

In addition to drawing holes and shafts, the four-center ellipse can be applied in the forming of rounds on corners of objects shown in isometric. You will observe that the angle at the corner of the object will be either acute (60°) or obtuse (120°) for the representation of a 90° angle depending upon location on the view.

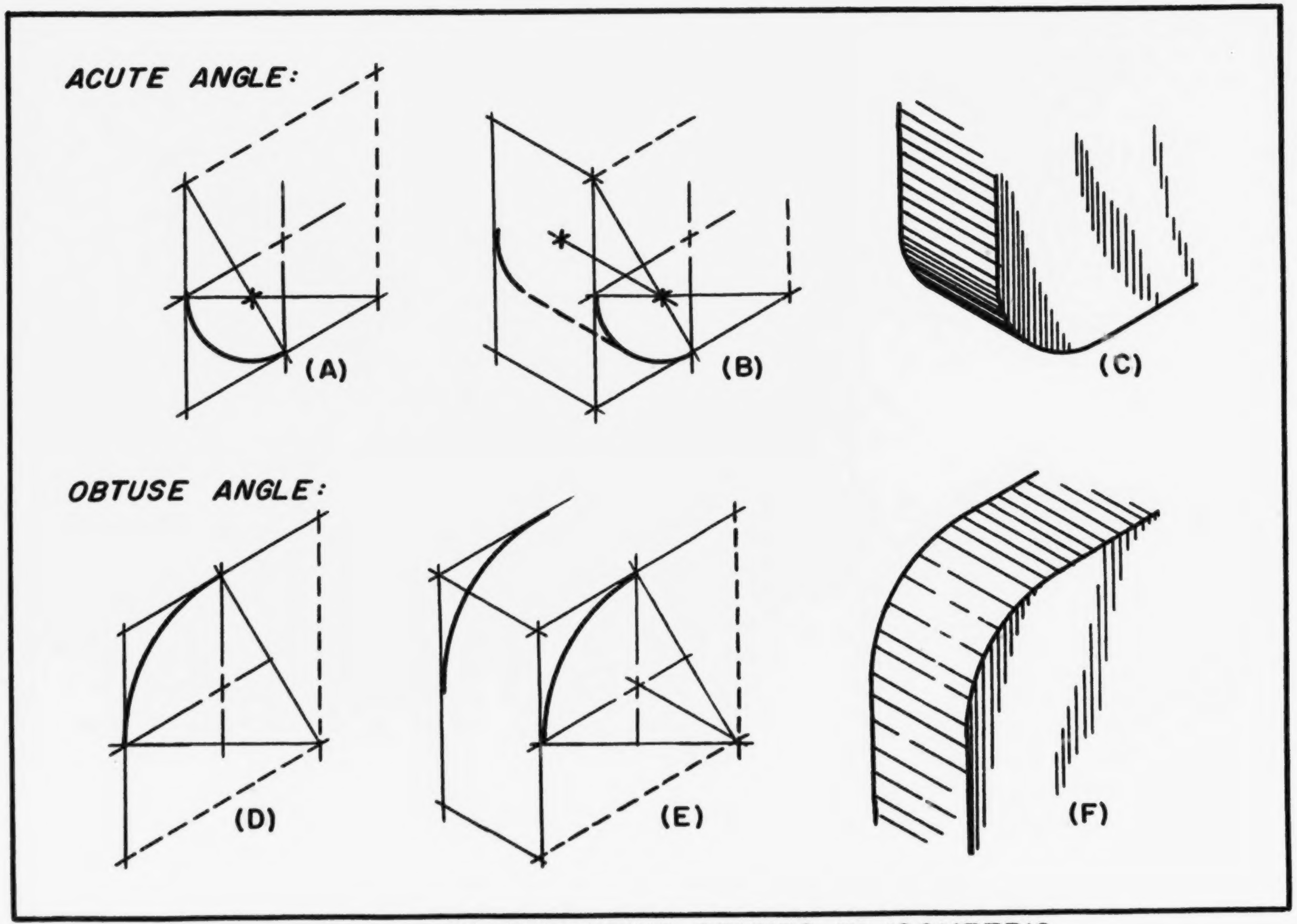

ACUTE ANGLE:
(A)
(B)
(C)
OBTUSE ANGLE:
(D)
(E)
(F)

Figure 4. CONSTRUCTING ROUNDS IN ISOMETRIC

Drawing Rounds at Corners

You will notice that only the portion of the original "square" which applies to the corner at which you are working must be drawn (figure 4). The method of transferring the ellipse construction center to the rear plane of the object is the same as for holes and shafts. Figure 4 (A), (B), and (C) relate "round" construction on the acute angle, and (D), (E), and (F) the construction for the obtuse angle. Apply these constructions in your work by using them on the proper isometric planes.

Note. The approximate four-center ellipse outlined may be applied satisfactorily in most drawing situations. However, it must be noted that the ellipse produced varies somewhat from a "true isometric ellipse." This is true because the approximate method is not projected in consideration of the 35°-16' tilt of the object used to attain the isometric view. As you will recall, a true ellipse is attained by projecting directly from the circle in its given position, not by changing the size of axes to suit a particular "instrument projection." (SEE LESSON 5, UNIT VI FOR FURTHER APPLICATIONS OF THE FOUR-CENTER ELLIPSE.)

ASSIGNMENT:

Using size A drawing paper with the simplified title block form, draw a 2½" cube in isometric centrally located on the page. On each of the three surfaces, draw an ellipse tangent to all four sides of that surface. Each side of the cube becomes the isometric "square" in which the ellipse is drawn. Title the drawing "FOUR-CENTER ELLIPSE." Dimension all three axes as described in Lesson 4, Unit VI, using two-place decimal fractions.

UNIT VI - ISOMETRIC DRAWING

Inclined Surfaces and Angles Lesson 3

OBJECTIVES:

1. To define "non-isometric lines."
2. To relate basic drawing lines and surfaces.
3. To explain representation of angles.

REFERENCES:

1. Chapter 15, TECHNICAL DRAWING, Giesecke, Mitchell, and Spencer.
2. Chapter 14, MECHANICAL DRAWING, French and Svensen.

INFORMATION:

Any line which is not drawn parallel to an isometric plane cannot be measured and drawn directly on an isometric view. Therefore, the placement of these "non-isometric" lines must be projected as a connection between two established points (figure 1a).

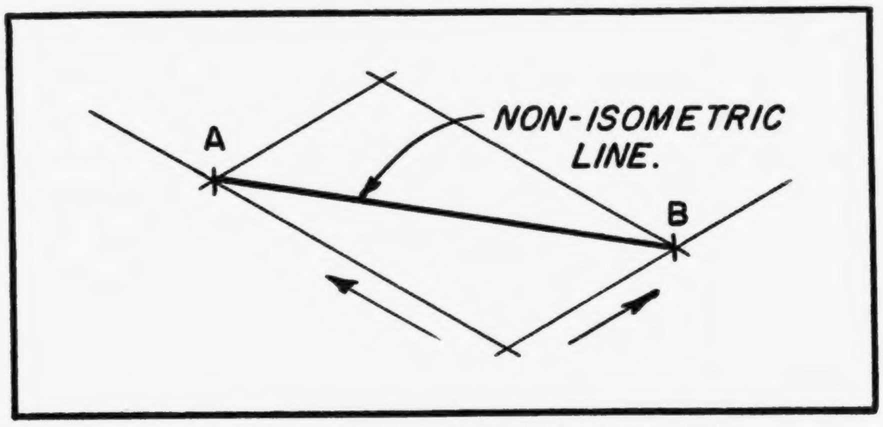


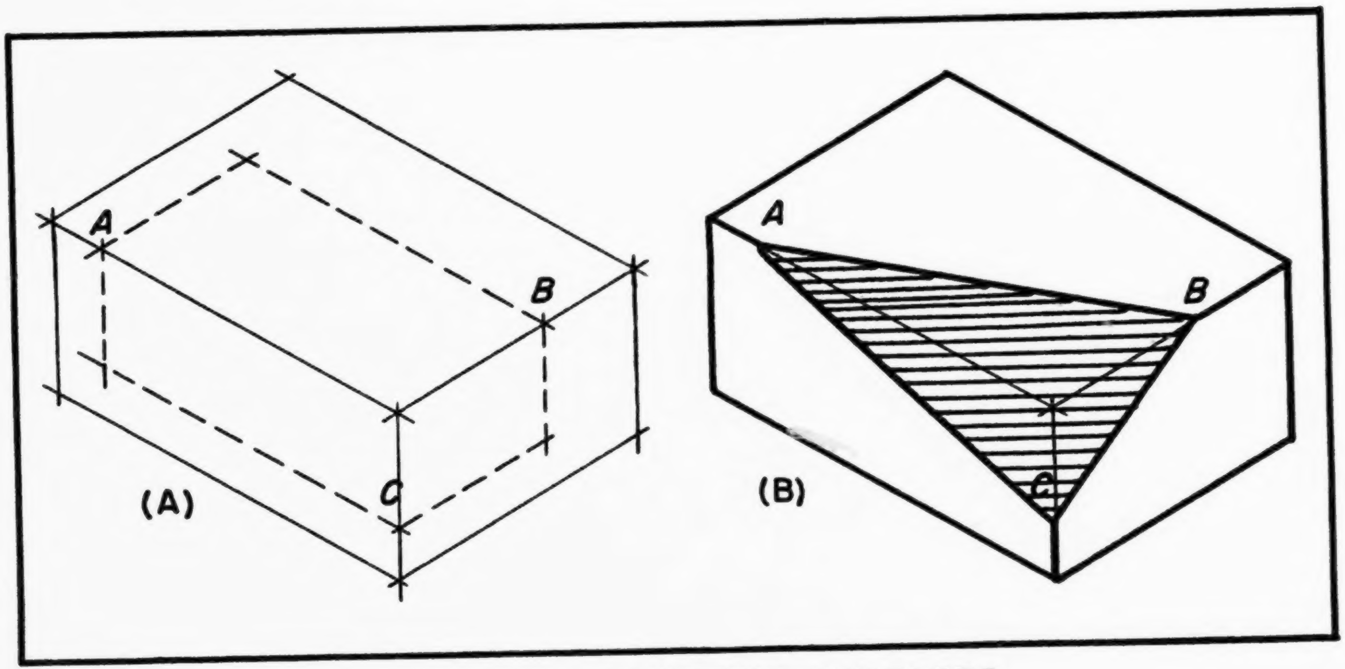
Figure 1.

NON-ISOMETRIC LINES

The ends of the lines (figure 1), represented by A and B, are located along established isometric guide lines measuring off the required distances.

Non-Isometric Surfaces

Non-isometric surfaces may be drawn by connecting a series of points (figure 2a) which have been located by measuring parallel to the related isometric edges.



NON- ISOMETRIC SURFACES

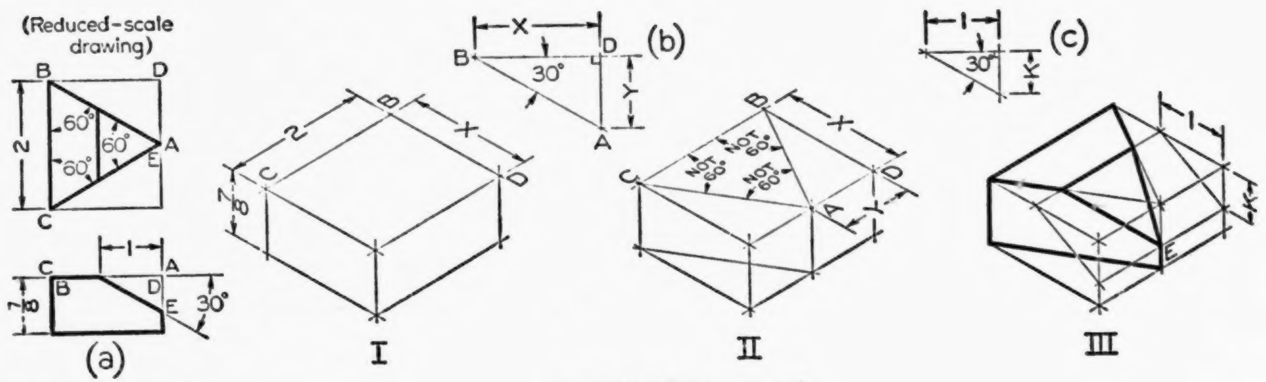
Figure 2.

Each point must be located by the intersection of two guide lines. By connecting these points the projection of the non-isometric surface (represented by shaded area in figure 2B) is completed.

Angles in Isometric

A "true projection" of angles cannot be made on isometric drawings since the actual included angles between object edges is changed with each change of position on the view.

Therefore, representations of angles must be drawn by much the same method as that given for non-isometric lines. An intersection of two measured distances must be used to find the relationship of the angle to the object edges.


(Reduced-scale drawing)
B
D
2
60°
60°
60°
A
E
C
C
1
A
7/8
B
D
E
30°
(a)
2
B
X
C
D
7/8
I
X
B
D
30°
Y
A
(b)
B
C
NOT 60°
NOT 60°
NOT 60°
X
A
D
Y
II
1
30°
K
(c)
1
K
E
III

Angles in Isometric.

Figure 3.

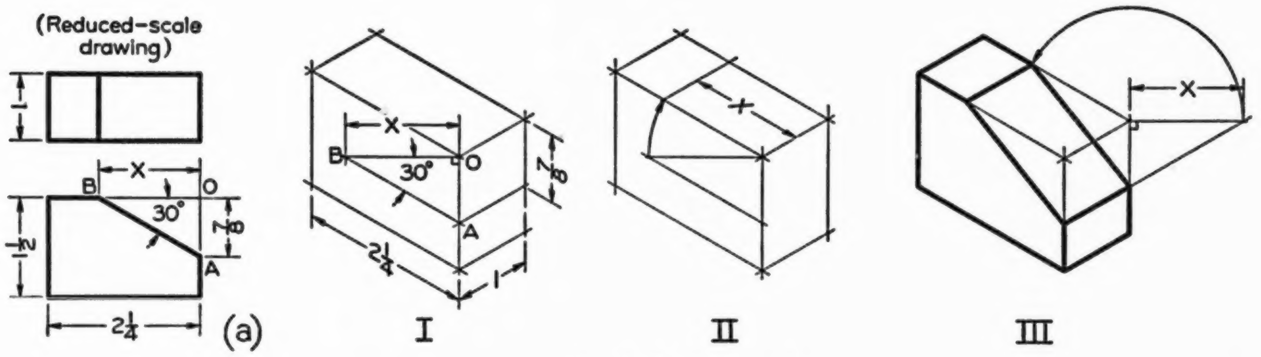
As seen at figure 3(a), the regular orthographic drawing of the object is referred to to locate the measured distance "offset" created by the angles along the sides of the object (lettered lines).

These distances are transferred to their corresponding positions on the isometric guide lines (I), and the hypotenuse of the triangular construction is used to represent the angle (II).

Related "offsets" for the other object planes (if any) are then located (III) to complete the construction.

Finding Unknown Linear Distances

Angles can be represented more easily in cases where the length of offsets are not known by connecting the graphic construction of the true angle to the isometric view.



Angle in Isometric.

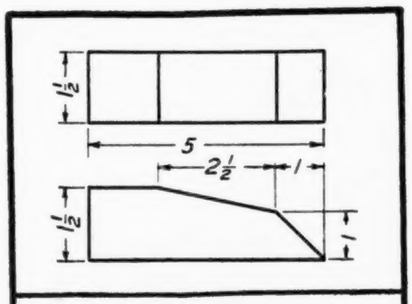
Figure 4.

Figure 4(a) shows an orthographic view in which only one offset is measured. By making a guide line construction of the actual angle located in reference to the proper surface, the unknown distance (x) is established (I).

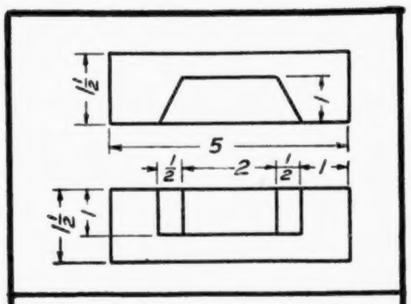
By swinging upward (in this instance), the previously unknown distance is established on the isometric view (II). At (III) an alternate position of the projected angle outside the view is shown. This can be done when it is not convenient to work within the area of the isometric view. In either case, the unknown distance is transferred and the object lines constructed to complete the drawing.

ASSIGNMENT:

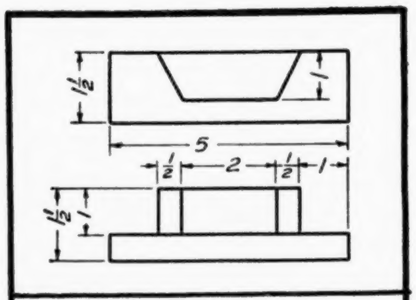
For homework, using plain white paper, make isometric sketches of problems 1-6. Be sure to show your use of proper guide lines for locating the offset surfaces and angles. Keep sketches proportionate to the form of the object. You do not have to measure when constructing these sketches.


1 1/2
5
2 1/2
1
1 1/2
1

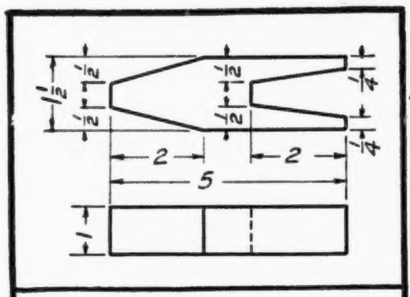
1 **WEDGE**


1 1/2
1
5
1/2
2
1/2
1
1 1/2
1

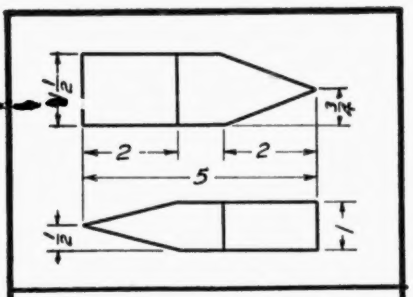
2 **RECESSED BLOCK**


1 1/2
1
5
1/2
2
1/2
1
1 1/2
1

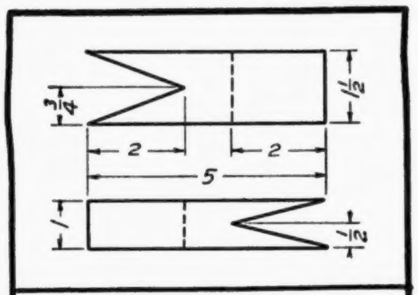
3 **BASE**


1 1/2
1/2
1/2
1/2
1/2
1/4
1/4
2
2
5
1

4 **SPLICE**


1 1/2
3/4
2
2
5
1/2
1

5 **DOUBLE WEDGE**

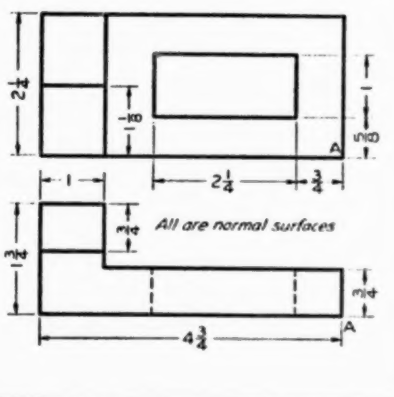

3/4
1 1/2
2
2
5
1
1/2

6 **TAPER SPLICE**

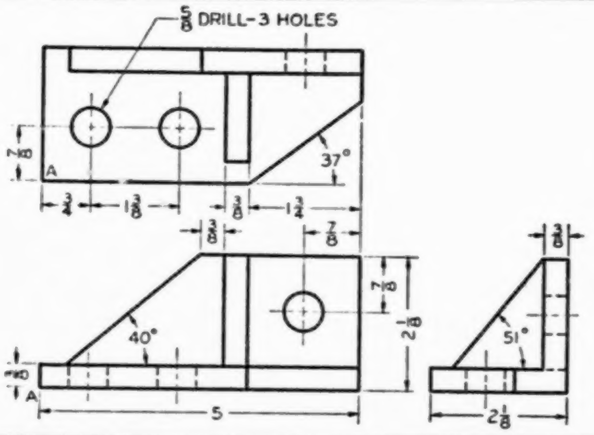
PROBLEMS 1 - 6 ***SKETCHING ASSIGNMENTS***

For classroom drawings, on size A paper using the simplified title block form, draw problems 7-10 in isometric. Show only the isometric view, centering it on the page to the best of your ability.

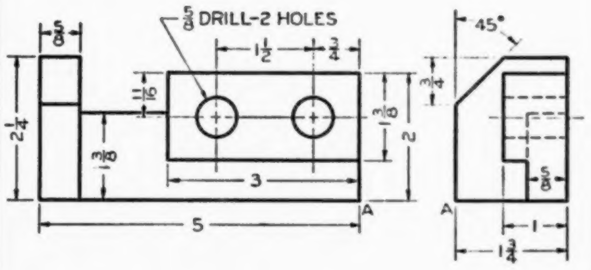
Dimension each drawing fully, following the procedures outlined in Lesson 4, Unit VI, of this course. Seek additional information from your text or instructor as necessary.


All are normal surfaces
A
A

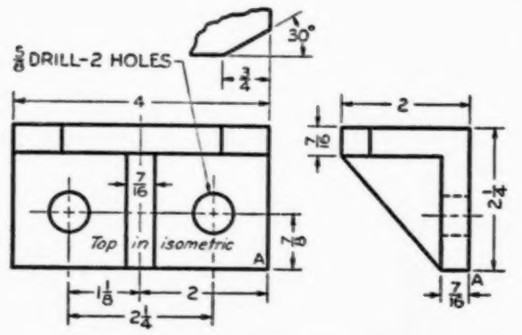
7 **KEY PLATE**


5/8 DRILL-3 HOLES
37°
40°
51°
A
A
5

8 **BRACKET NO. I**


5/8 DRILL-2 HOLES
45°
3
5
2
A
A

9 **CUTTER BLOCK**


5/8 DRILL-2 HOLES
30°
4
2
Top in isometric
A
A

10 **BRACKET NO. 2**

PROBLEMS 7 - 10 ***DRAWING ASSIGNMENTS***

UNIT VI - ISOMETRIC DRAWING

Dimensioning Isometric Drawings Lesson 4

OBJECTIVE:

1. To relate the procedures for supplying dimensions on isometric drawings.

REFERENCES:

1. Chapter 15, TECHNICAL DRAWING, Giesecke, Mitchell, and Spencer.
2. Chapter 12, ENGINEERING DRAWING, Zozzora.

INFORMATION:

The basic rules for dimensioning outlined for orthographic projection (Lesson 1, Unit IV) apply directly to isometric drawing. The only difference is that dimensions are drawn pictorially on isometric drawings.

As is the rule in multiple view drawings, the dimension, extension, and figure guide lines on isometric views are constructed parallel to the several planes of projection.

Numeral Construction

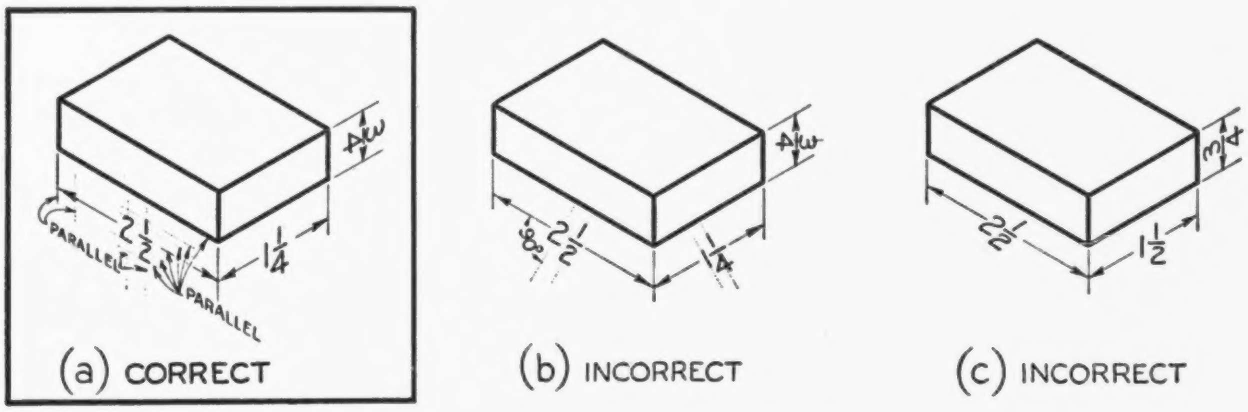


Figure 1.

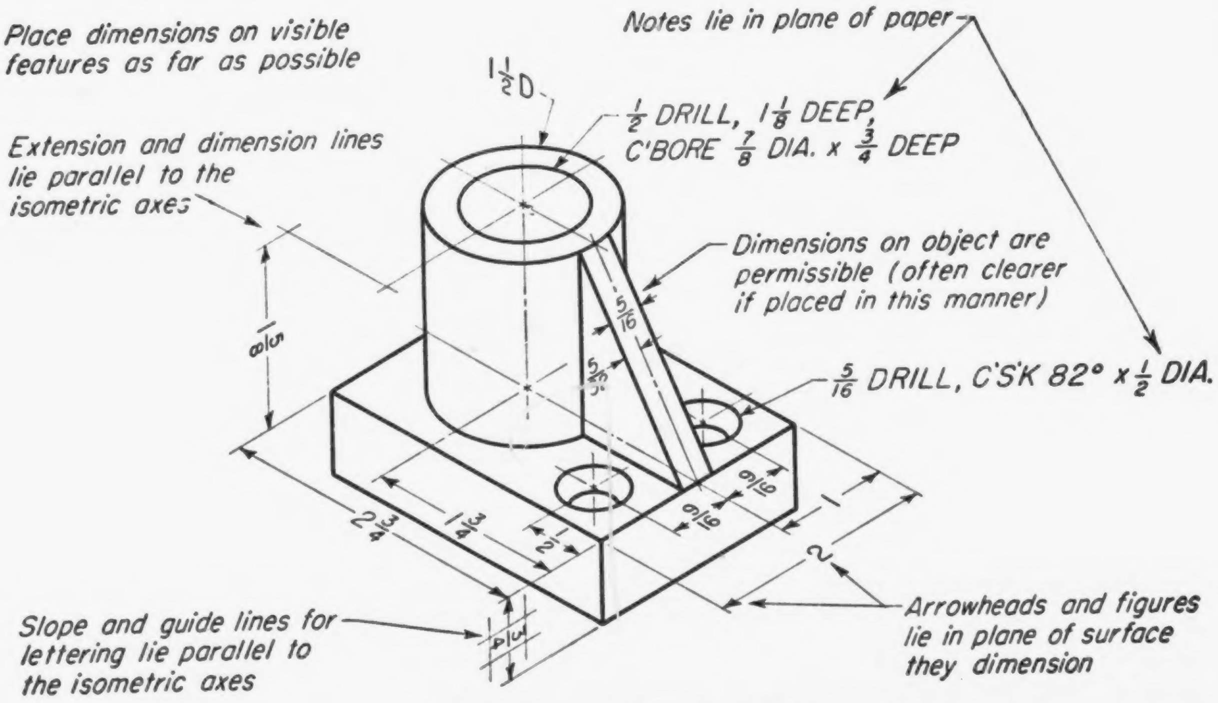
Numerals and Arrowheads in Isometric.

Figure 1 illustrates the construction of numerals and their related dimension and extension lines for describing the width, depth, and height of the object.

Notice particularly that the numerals for horizontal measurements are drawn vertically. The horizontal lines in the numerals follow the horizontal isometric axes.

Numerals for vertical dimensions should be drawn with their base oriented to the central point of the drawing. Horizontal portions of the figures in this case follow the vertical axis of the object. Common errors of figure position are shown in figure 1(b-c).

Arrowheads


1 1/2 D
1/2 DRILL, 1 1/8 DEEP, C'BORE 7/8 DIA. x 3/4 DEEP
5/16 DRILL, C'SK 82° x 1/2 DIA.
5/8
5/16
5/16
2 3/4
1 3/4
1/2
9/16
9/16
1
2
3/4

Place dimensions on visible features as far as possible

Extension and dimension lines lie parallel to the isometric axes

Notes lie in plane of paper

Dimensions on object are permissible (often clearer if placed in this manner)

Slope and guide lines for lettering lie parallel to the isometric axes

Arrowheads and figures lie in plane of surface they dimension

Rules for dimensioning an isometric drawing.

Figure 2.

The rear portions of arrowheads should fall parallel to the extension lines in any of the three planes. Do not be afraid to use guide lines when first drawing arrowheads in isometric.

Notes and Leaders

All notes describing features of objects should be drawn horizontally on the page. Leaders may extend to the object from any convenient direction as long as they do not fall either horizontally or vertically on the page at their point of contact with the object (figures 2 and 3).

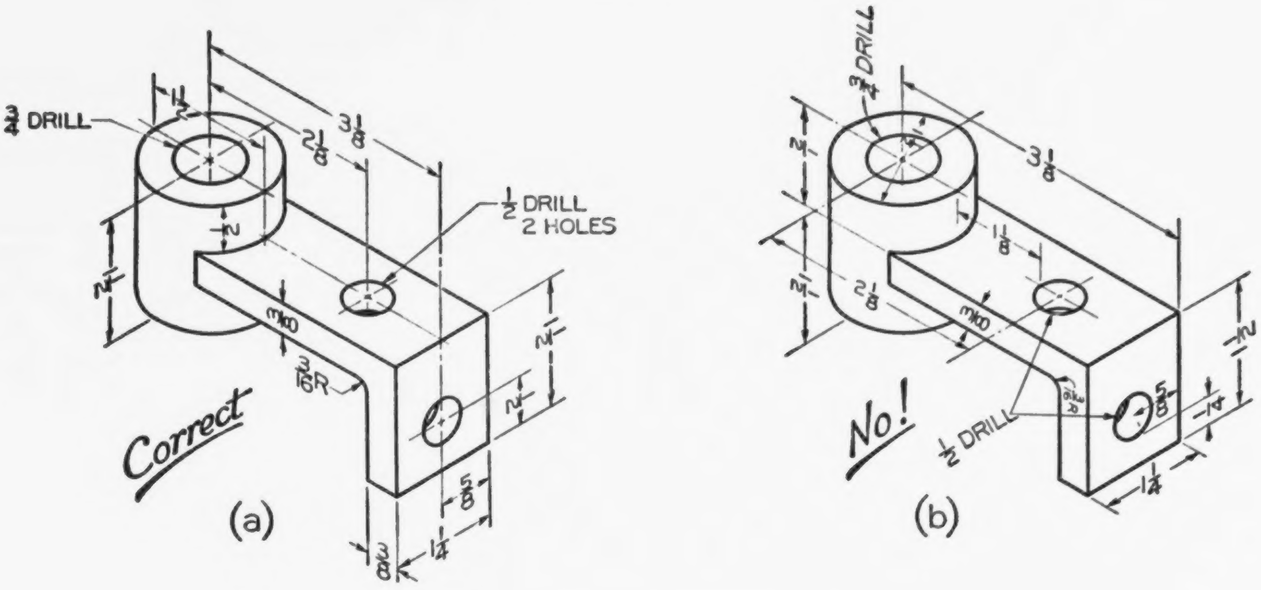

3/4 DRILL
1 1/2
3 1/8
2 1/8
1/2 DRILL
2 HOLES
1/2
3/8
3/16 R
5/8
1 1/4
Correct
(a)
3/4 DRILL
3 1/8
1 1/8
2 1/8
3/8
1/2 DRILL
5/8
1 1/4
No!
(b)

Figure 3. Common Dimensioning Errors

Figure 3(b) indicates some common errors made when dimensioning an isometric drawing. Be careful to:

1. place all notes horizontally on the page.
2. draw both extension lines limiting a dimension on the same plane of reference. (IF THIS RULE IS NOT FOLLOWED, THE DIMENSION LINES WILL NOT APPEAR IN THEIR TRUE LENGTH.
3. draw all dimensions directly parallel to the axis being described.
4. place all dimensions effectively where they can be most clearly "read". Do not crowd dimensions or notes on the drawing.

ASSIGNMENT:

Apply the above dimensioning techniques to the problems assigned in lessons 1 through 3, this unit.

UNIT VI - ISOMETRIC DRAWING

Related Working Drawing Techniques

Lesson 5

OBJECTIVES:

1. To relate the importance of making good pictorial drawings.
2. To show how isometric pictorials can be used with or to replace other working drawings.
3. To relate pictorial methods of constructing threads and hexagonal bolts.
4. To show drawing techniques for isometric sections.
5. To introduce exploded assemblies.

REFERENCES:

1. Chapter 15, TECHNICAL DRAWING, Giesecke, Mitchell, and Spencer.
2. Chapter 12, ENGINEERING DRAWING, Zozzora.

INFORMATION:

The use of accurate pictorial drawings of objects is quite necessary in many instances to relate an understanding of ideas to persons not familiar with technical drawing principles. By providing a well executed pictorial drawing, insight as to "what" the object is and to its "basic form" is immediately effected.

The use of pictorial drawings is economical in many fields. In industrial manufacturing concerns, for example, the cutting of production time can be accomplished by supplying pictorial assembly drawings to the assembly operator in place of mechanical detail drawings. The consumer advertising industry uses pictorial drawings to sell its products. For instance, of what value to the consumer is a detail drawing of a motor mount when the purchase of an automobile is in question? Through these and other applications observed every day you can see pictorial drawings used either to supplement detail drawings or replace them entirely when possible.

Applied Drawing Techniques

In detail drawings the draftsman is not usually concerned with a true pictorial representation of the object. There are certain basic techniques which are used to represent detail on pictorial drawings which you should apply from the start.

Fillets and Rounds

As you continue in drawing there will be times when it is necessary to represent fillets or rounded edges in isometric. It is not the purpose of this lesson to demonstrate the use of shading to the extent used on display drawings, but rather to show techniques of describing basic form.

One simple method of showing fillets and rounds in isometric is by using short curved lines spaced about one-eighth inch apart. These shading lines follow the direction of the fillet or round and terminate at the point where the fillet or round blends with the adjacent surface.

STUDY THE PICTORIAL SKETCHES GIVEN FOR PREVIOUS WORKING DRAWING PROBLEMS.

It is suggested that guide lines be used to limit the extent of shade lines to give a neat "straight line" appearance to the finished drawing. All object lines of the pictorial should be drawn first, placing the curved shade lines along fillets and rounds last,projecting them from finished edges.

Make guide lines extremely light to avoid erasing over the areas where fillets and rounds are represented. The shade lines are light, comparing in weight to section lines.

Threads

Except where threads are shown in section, the "V" form of threads or the regular schematic representations are not applicable to isometric pictorials. Threads are shown pictorially by means of a series of ellipses equal to the major diameter of the thread (either external or internal) spaced at convenient intervals to represent "pitch."

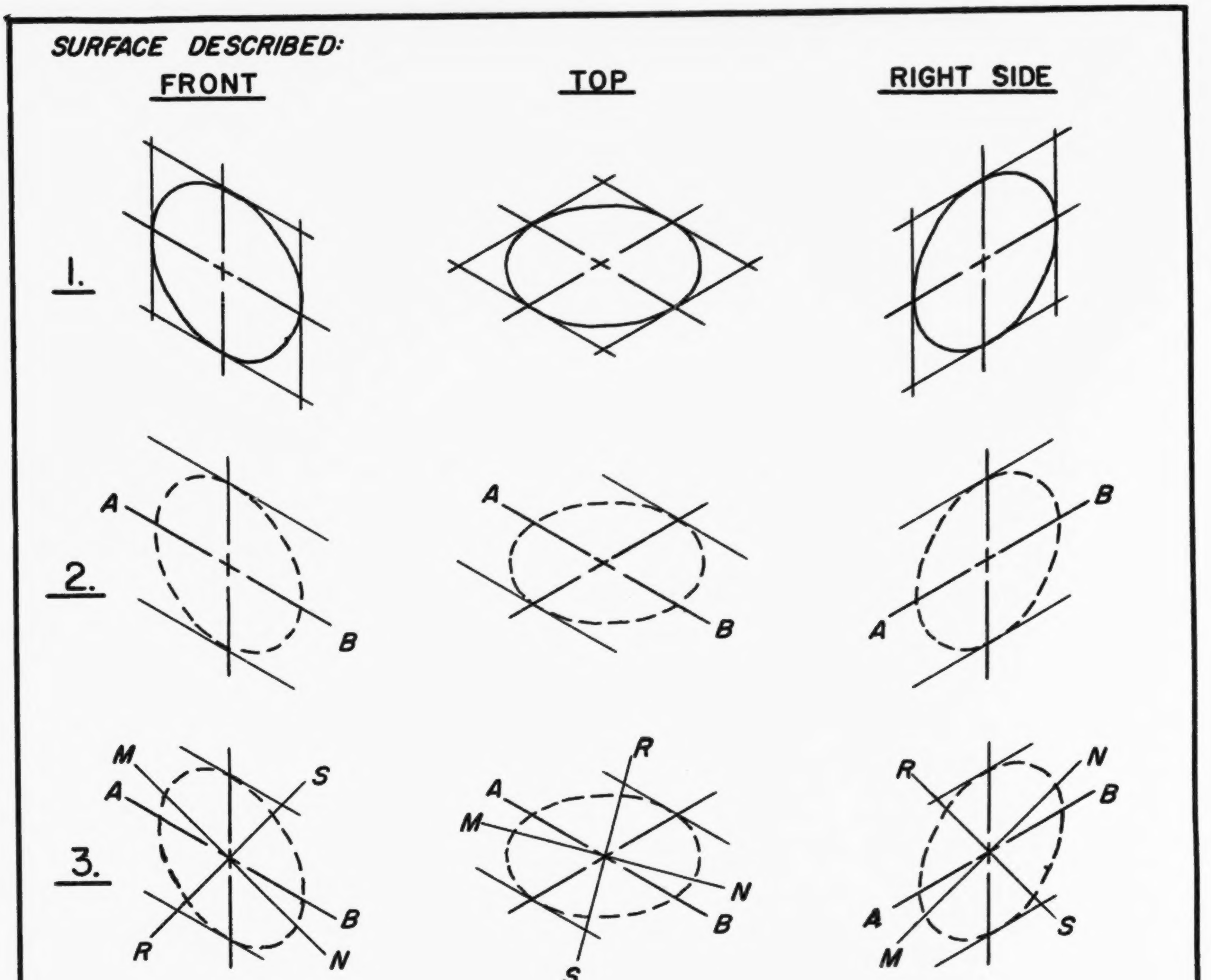
The pitch of threads need not be represented exactly since notes describing the pitch are provided in the detail drawing. You may represent threads of any pitch according to the following suggested spacings given according to diameter of the thread:

$\frac{1}{4}$" - $\frac{7}{16}$" use $\frac{1}{16}$" spacing

$\frac{1}{2}$" - $\frac{11}{16}$" use $\frac{3}{32}$" spacing

$\frac{3}{4}$" - 1" use $\frac{1}{8}$" spacing

For threads beyond these size limits use a convenient spacing which will clearly show the threaded areas. The lines should be of good quality approaching the weight of the object lines.


SURFACE DESCRIBED:
FRONT
TOP
RIGHT SIDE
1.
2.
3.
4.
5.
A
B
M
N
R
S
1
2
3
DWN. BY: T.C. MOSLEY, JR.

HEXAGON CONSTRUCTION: *FOUR-CENTER ELLIPSE*

Figure 1.

Bolts and Nuts

When drawing nuts and bolts, the tables of standards for these parts should be followed. Pictorial representation of nuts and bolts is necessary especially with isometric assemblies. Be careful to follow the standards for thread length and head formation except in special cases where specifications are given.

Drawing Hexagons in Isometric

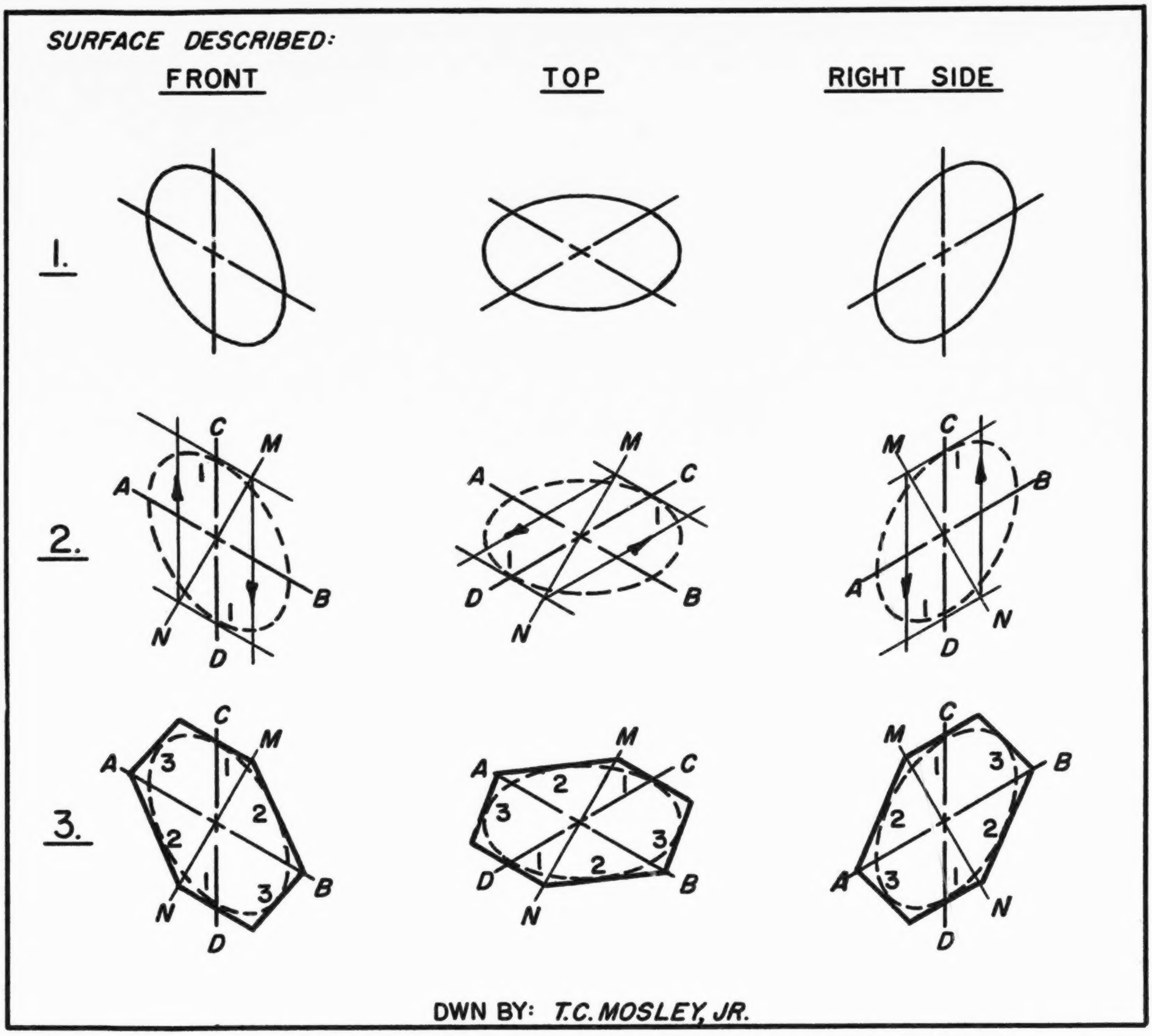
The application of geometric constructions is often important in isometric drawing. One geometric construction used often for isometric pictorials, particularly for representations of hexagonal nuts and bolts, is the drawing of a hexagon tangent to an inscribed circle.

Explained below is a method, developed by the author, for drawing hexagons isometrically tangent to the approximate four-center ellipse outlined in Lesson 2, using the 45° triangle and 30-60° triangle both separately and in combination.

It will be noticed that constructions are shown parallel to the three regular isometric planes (front, top, and right side), and that two positions of the hexagon are possible in each plane depending upon which axis is run parallel to a pair of "flats." (SEE BOTTOM OF FIGURE 1.)

Steps of Construction: (follow steps in figure 1)

1. Construct a four-center ellipse on the desired plane. Include the center axis.
2. Designate one center axis as AB. Draw guide lines parallel to this axis.
3. Construct line MN offset 15° from AB. Construct a perpendicular RS to line MN.
4. The first pair of "flats" (1) are drawn parallel to axis AB. The second pair of "flats" (2) are drawn parallel to RS from points A and B respectively, and limit the first pair of "flats" (1) at their opposite ends. The third pair of "flats" (3) are drawn at a 15° angle to the unmarked center axis by combining both the 45° and 30°-60° triangles in the required positions. Darken the six sides to complete the construction.
5. Alternate positions of the hexagons in each plane are achieved by designating the opposite center axis as AB and following steps 2-4.


SURFACE DESCRIBED:
FRONT
TOP
RIGHT SIDE
1.
2.
3.
A
B
C
D
M
N
1
2
3
DWN BY: T.C. MOSLEY, JR.

HEXAGON CONSTRUCTION: *TRUE ISOMETRIC ELLIPSE*

Figure 2.

Use of Isometric Ellipse Templet

You have probably noticed in your work that the construction of ellipses by the four-center method requires substantial drawing time. Since reduction of time spent on drawings is important in many cases, the use of templets for common construction is sometimes considered necessary.

For your future work you may, if desired, use a commercial ellipse templet for isometric constructions, especially for drawing threads.

IT MUST BE NOTED, however, that the true isometric ellipse does differ in form from the four-center ellipse. This will cause differences in size and form for pictorial representations of circular details. Geometric constructions tangent to the "true" isometric ellipse also require varied techniques.

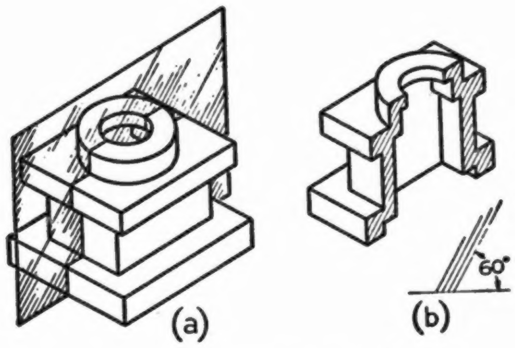
Note. THE CONSTRUCTION OF HEXAGONS TANGENT TO THE FOUR-CENTER ELLIPSE (figure 1) IS NOT APPLICABLE WITH THE "TRUE" ISOMETRIC ELLIPSE SINCE THE ANGLES AT WHICH THE SIDES ARE DRAWN CANNOT BE CONSTRUCTED DIRECTLY WITH THE COMBINATION OF TRIANGLES.

Steps taken to construct a hexagon tangent to the true isometric ellipse are outlined below. (Follow the steps illustrated by figure 2.)

1. Locate coordinates and draw the true isometric ellipse ($35^{\circ}16'$) using a templet.
2. Designate one axis as AB and the others as CD. Draw guide lines tangent to the ellipse parallel to AB. Draw a line MN offset 30° from axis CD intersecting the quadrant of the ellipse nearest the minor axis. Limit the length of the first pair of flats (1) by running lines (shown by arrows) parallel to CD from the intersection of MN with the guide lines drawn parallel to AB above.
3. By moving both the triangles and T-square together, set up a tangent to the ellipse and draw a second pair of "flats" (2) from points M and N respectively to axis AB. Draw the final pair of "flats" (3) tangent to the ellipse intersecting the unmarked ends of "flats" (1) and points A and B respectively to complete the hexagon.

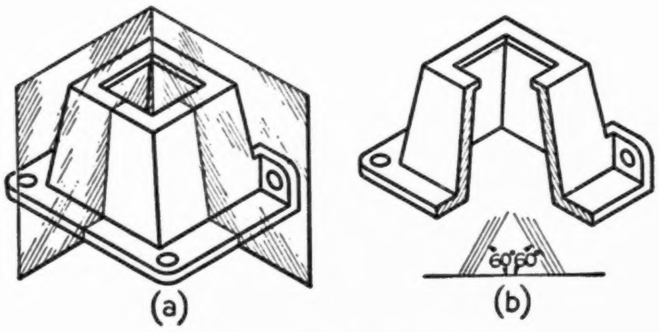
Sections in Isometric

As is true of sections in multiview projection, a description of interior object detail in relation to exterior detail can be given by applying section in isometric drawing.



Isometric Full Section

Figure 3.



Isometric Half Section.

Figure 4.

As shown in figures 3 and 4, a section in isometric is produced by passing the cutting plane through the center of the object parallel to one or more of the receding isometric axes.

Section lines at the "cut" surfaces are usually drawn from 60° to horizontal except where they would fall parallel to adjacent object lines.

In full sections (figure 3) the section lines should run in the same direction in isolated portions. For half sections, the accepted technique is to run the section lines converging toward center on the opposed surfaces (figure 4).

Of the two types of sections, half sections seem to be the most useful on isometric drawings since a clear relationship of internal and exterior details is easily attained.

Broken sections are also used quite often in isometric drawing. Any necessary portion may be broken away to show a surface parallel to an isometric plane. Section line techniques are the same as for full and half sections.

Pictorial Assemblies

Pictorial assemblies, such as the production illustration shown in figure 5 or the exploded isometric shown in figure 6, are used quite often in industrial and commercial applications to describe the relationship parts in mechanisms.

Figures 5 and 6 are advanced applications of isometric drawing and are included here to give further insight as to the possible uses of pictorial drawing.

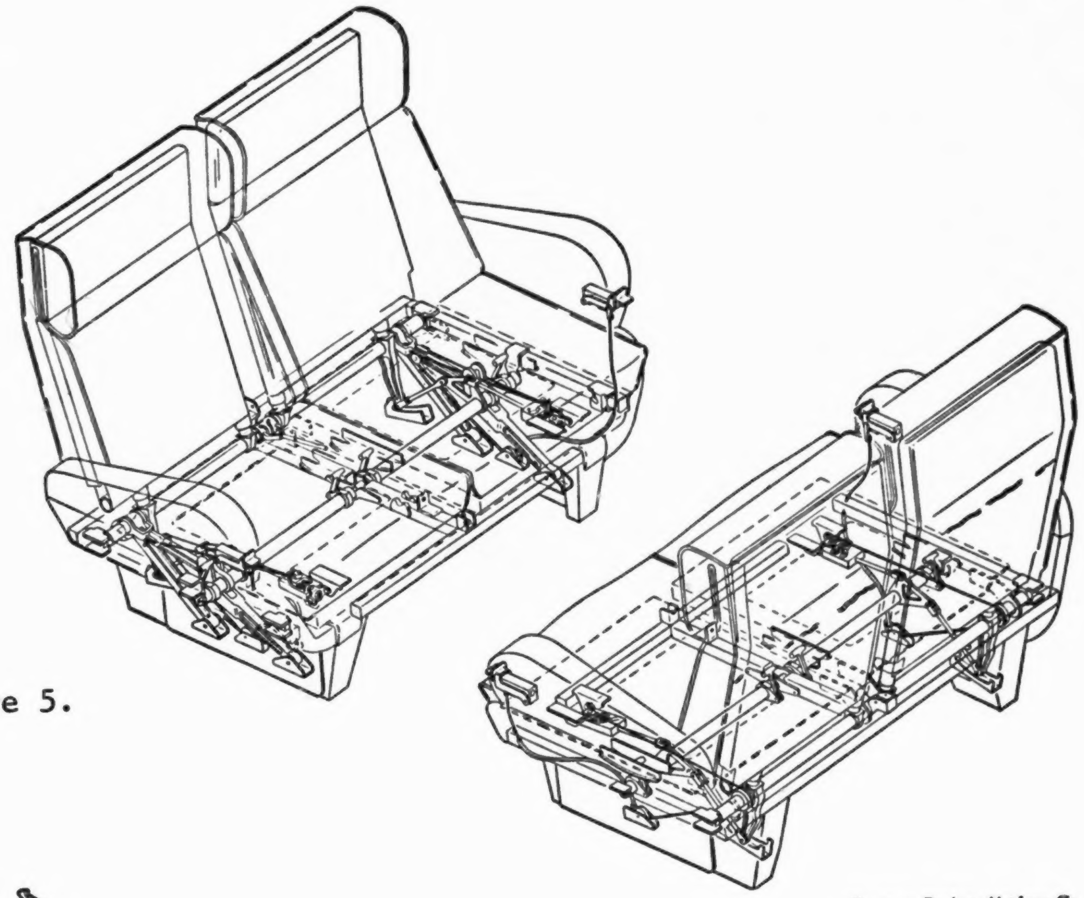
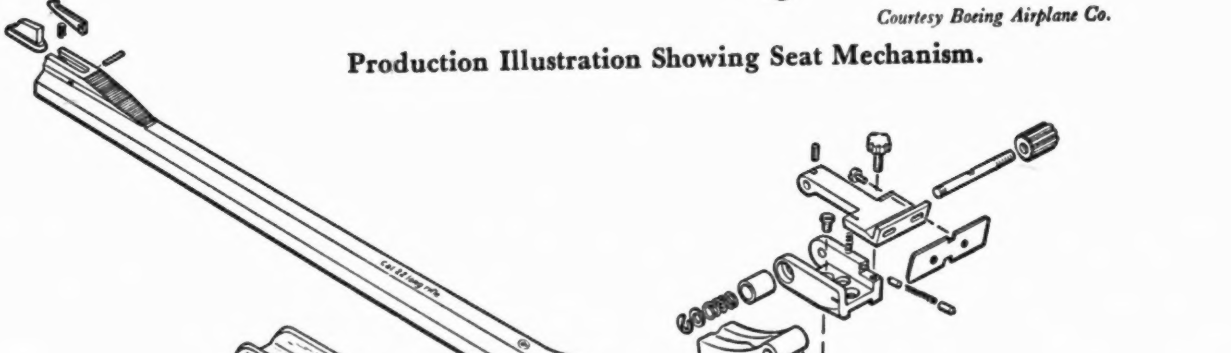


Figure 5.

Courtesy Boeing Airplane Co.

Production Illustration Showing Seat Mechanism.



Courtesy of True Magazine *c 1955, Fawcett Publications.*

Figure 6.

Isometric Exploded Assembly of Hammerli Match Pistol.

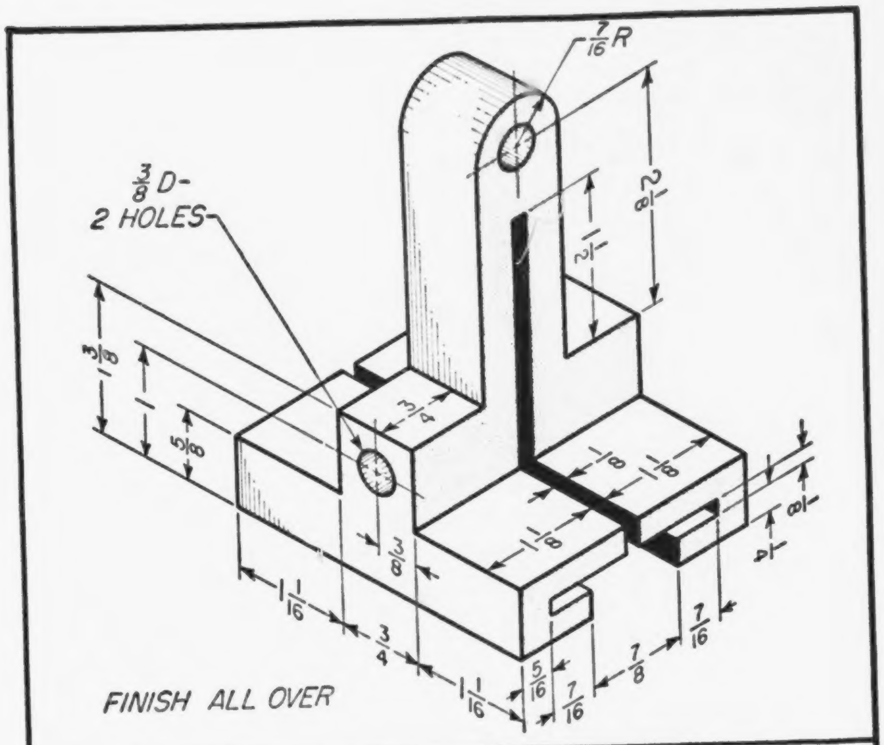
Work employing these principles may be attempted in connection with the final project outlined in Lesson 1, Unit VII. Use text references for description of related drawing techniques.

ASSIGNMENT:

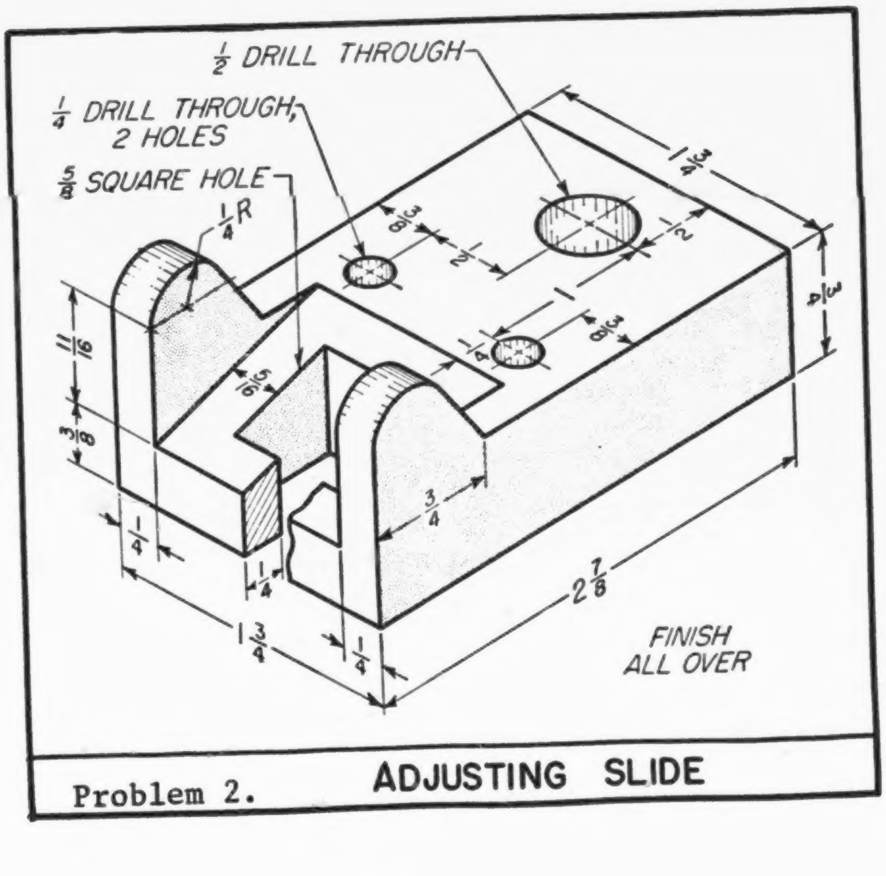
The illustrationsfor problems 1 and 2 show parts made from cold rolled steel. Using size B paper, draw the necessary orthographic view for the same parts made from cast iron. Show fillets and rounds of $\frac{1}{8}$" radius on all cast edges and corners.

Threads are to be drawn having diameters equal to the lower hole in Problem 1 and in the $\frac{1}{2}$" hole in Problem 2. Use a standard pitch recommended for UNC series (see appendix). Use sections as you think necessary. Supply all dimensions and required notes.

Draw an isometric pictorial view of the redesigned part at the right side of your drawings. Show fillets and rounds and required threads as described in this lesson.


7/16 R
3/8 D-
2 HOLES
2 1/8
1 1/2
1 3/8
1
5/8
3/4
1/8
1/8
1/8
1/8
1/4
3/8
1 1/16
3/4
1 1/16
5/16
7/16
7/8
7/16
FINISH ALL OVER

Problem 1. **ADJUSTING CLAMP**


1/2 DRILL THROUGH
1/4 DRILL THROUGH,
2 HOLES
5/8 SQUARE HOLE
1/4 R
1 3/4
3/8
1/2
1/2
1
3/8
1/4
3/4
5/16
11/16
3/8
1/4
1/4
3/4
2 7/8
1 3/4
1/4
FINISH
ALL OVER

Problem 2. **ADJUSTING SLIDE**

UNIT VII - CONCLUSION

Summary and Final Project

Lesson 1

OBJECTIVES:

1. To summarize the importance of the work detailed in this course.
2. To supply suggested assignments correlating the outlined drafting techniques.

INFORMATION:

The techniques and methods outlined in the several lessons of this course were presented with the objective of developing the skills and understanding of the student concerning basic technical drawing.

The "projections" of views presented in this course are basic to all technical drawing assignments. A well-developed sense of neatness and accuracy and the understanding of these basic techniques and their applications will take you a long way in your future drafting experience in school and in employment.

As you progress, new techniques and procedures will be realized. This course, by no means, is to be considered an end in itself. Much remains to be learned.

It is suggested that you continue your drawing education in school if at all possible,and seek additional knowledge from instructors or other professional personnel possessing a sound knowledge of drafting techniques. Keep an open mind on the subject and be ready to accept new and related techniques in drawing. The field of drafting is by no means a stagnant profession. New materials, machines, and methods are developed for the draftsman each day. Study is important to keep abreast of the advances being made.

Final Project

This year you have discovered many methods of representing and describing objects by means of mechanical drawings. To summarize your acquired skills, it is suggested that you employ as many techniques as possible in a single project to realize more fully how the separate techniques can be applied in working drawings.

Use of regular orthographic views, auxiliary views, sections, conventions, and pictorial views with their descriptive notes and dimensions all find important applications in drawings. Use them in your future work. Don't let progress stop with the end of this course.

QUESTIONS:

1. From related readings, list four methods of pictorial drawing in addition to isometric.
2. To what profession are all drawing reproduction methods related? How?
3. What is the basic importance of mechanical drawing?
4. List five periodical publications in which you have found applications of mechanical drawings. How were they used?
5. List two common products which may require pictorial assemblies to provide adequate description.

ASSIGNMENT:

Choose a working drawing problem* of a machine assembly having several parts. Apply the following methods in your drawing:

1. Make detail drawings of each of the parts. Use multiple detail sheets where possible with required parts listings.
2. Draw isometric pictorials of the individual parts where further description is necessary.
3. Use auxiliary views and sections where possible.
4. Draw a sectional assembly (single-view orthographic) of the entire problem. Use parts identification numbers.

*Suggested Problems

Many suitable problems are given at the end of Chapter 14, "Working Drawings", TECHNICAL DRAWING, 4th edition, Giesecke, Mitchell, and Spencer.

It should be left to the instructor to choose problems suited to the students' capabilities.

5. Substitute tracing Vellum for drawing paper and make "prints" of your drawings. (FOR A DESCRIPTION OF DRAWING REPRODUCTION METHODS, SEEK REFERENCE TEXTS AND TALK WITH YOUR INSTRUCTOR.)

SUGGESTED RESEARCH ASSIGNMENTS:

1. Choose one industry and discuss how mechanical drawing is related directly to its operation.
2. Discuss one advanced development in the drafting industry. Example: the "Automatic Drafting Machine."
3. Discuss mechanical drawing in relationship to commercial advertising. Supplement with illustrations.
4. Contact a local industry (in person if possible) and discuss its draftsman training or apprentice program. Include a discussion on how your present training relates to the industrial program.

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Giesecke, Mitchell, and Spencer, TECHNICAL DRAWING, 4th edition, New York, 1958, The MacMillan Company.

Zozzora, F., ENGINEERING DRAWING, New York, 1953, McGraw-Hill Book Company, Incorporated.

APPENDIX NO. 1

DECIMAL EQUIVALENTS

Fractions	Decimal	Fractions	Decimal
1/64	.0156	33/64	.5156
1/32	.0313	17/32	.5313
3/64	.0469	35/64	.5469
1/16	.0625	9/16	.5625
5/64	.0781	37/64	.5781
3/32	.0938	19/32	.5938
7/64	.1094	39/64	.6094
1/8	.1250	5/8	.6250
9/64	.1406	41/64	.6406
5/32	.1563	21/32	.6563
11/64	.1719	43/64	.6719
3/16	.1875	11/16	.6875
13/64	.2031	45/64	.7031
7/32	.2188	23/32	.7188
15/64	.2344	47/64	.7344
1/4	.2500	3/4	.7500
17/64	.2656	49/64	.7656
9/32	.2813	25/32	.7813
19/64	.2969	51/64	.7969
5/16	.3125	13/16	.8125
21/64	.3281	53/64	.8281
11/32	.3438	27/32	.8438
23/64	.3594	55/64	.8594
3/8	.3750	7/8	.8750
25/64	.3906	57/64	.8906
13/32	.4063	29/32	.9063
27/64	.4219	59/64	.9219
7/16	.4375	15/16	.9375
29/64	.4531	61/64	.9531
15/32	.4688	31/32	.9688
31/64	.4844	63/64	.9844
1/2	.5000	1	1.0000

MISCELLANEOUS INFORMATION

$\pi = 3.1416$. Area of circle $= \pi r^2$
1 inch = 2.54 centimeters
1 mile = 5280 feet
1 acre = 43560 square feet
1 U. S. gallon = 231 cu. in. = 4 quarts = 8 pints.
1 horsepower = 746 watts = 33000 ft. lbs./min.
1 Btu. = 1052 watt-sec. = 778 ft. lbs.

APPENDIX 2

AMERICAN STANDARD ABBREVIATIONS FOR USE ON DRAWINGS

(From ASA Z32.13—1950)

A

Absolute	ABS
Accelerate	ACCEL
Accessory	ACCESS.
Account	ACCT
Accumulate	ACCUM
Actual	ACT.
Adapter	ADPT
Addendum	ADD.
Addition	ADD.
Adjust	ADJ
Advance	ADV
After	AFT.
Aggregate	AGGR
Air Condition	AIR COND
Airplane	APL
Allowance	ALLOW
Alloy	ALY
Alteration	ALT
Alternate	ALT
Alternating Current	AC
Altitude	ALT
Aluminum	AL
American Standard	AMER STD
American Wire Gage	AWG
Amount	AMT
Ampere	AMP
Amplifier	AMPL
Anneal	ANL
Antenna	ANT.
Apartment	APT.
Apparatus	APP
Appendix	APPX
Approved	APPD
Approximate	APPROX
Arc Weld	ARC/W
Area	A
Armature	ARM.
Armor Plate	ARM-PL
Army Navy	AN
Arrange	ARR.
Artificial	ART.
Asbestos	ASB
Asphalt	ASPH
Assemble	ASSEM
Assembly	ASSY
Assistant	ASST
Associate	ASSOC
Association	ASSN
Atomic	AT
Audible	AUD
Audio Frequency	AF
Authorized	AUTH
Automatic	AUTO
Auto-Transformer	AUTO TR
Auxiliary	AUX
Avenue	AVE
Average	AVG
Aviation	AVI
Azimuth	AZ

B

Babbitt	BAB
Back Feed	BF
Back Pressure	BP
Back to Back	B to B
Backface	BF
Balance	BAL
Ball Bearing	BB
Barometer	BAR
Base Line	BL
Base Plate	BP
Bearing	BRG
Bench Mark	BM
Bending Moment	M
Bent	BT
Bessemer	BESS
Between	BET.
Between Centers	BC
Between Perpendiculars	BP
Bevel	BEV
Bill of Material	B/M
Birmingham Wire Gage	BWG
Blank	BLK
Block	BLK
Blueprint	BP
Board	BD
Boiler	BLR
Boiler Feed	BF
Boiler Horsepower	BHP
Boiling Point	BP
Bolt Circle	BC
Both Faces	BF
Both Sides	BS
Both Ways	BW
Bottom	BOT
Bottom Chord	BC
Bottom Face	BF
Bracket	BRKT
Brake	BK
Brake Horsepower	BHP
Brass	BRS
Brazing	BRZG
Break	BRK
Brinell Hardness	BH
British Standard	BR STD
British Thermal Units	BTU
Broach	BRO
Bronze	BRZ
Brown & Sharpe (Wire Gage, same as AWG)	B&S
Building	BLDG
Bulkhead	BHD
Burnish	BNH
Bushing	BUSH.
Button	BUT.

C

Cabinet	CAB.
Calculate	CALC
Calibrate	CAL
Cap Screw	CAP SCR
Capacity	CAP
Carburetor	CARB
Carburize	CARB
Carriage	CRG
Case Harden	CH
Cast Iron	CI
Cast Steel	CS
Casting	CSTG
Castle Nut	CAS NUT
Catalogue	CAT.
Cement	CEM
Center	CTR
Center Line	CL
Center of Gravity	CG
Center of Pressure	CP
Center to Center	C to C

APPENDIX 2 (CON'T)

Centering	CTR
Chamfer	CHAM
Change	CHG
Channel	CHAN
Check	CHK
Check Valve	CV
Chord	CHD
Circle	CIR
Circular	CIR
Circular Pitch	CP
Circumference	CIRC
Clear	CLR
Clearance	CL
Clockwise	CW
Coated	CTD
Cold Drawn	CD
Cold Drawn Steel	CDS
Cold Finish	CF
Cold Punched	CP
Cold Rolled	CR
Cold Rolled Steel	CRS
Combination	COMB.
Combustion	COMB
Commercial	COML
Company	CO
Complete	COMPL
Concentric	CONC
Concrete	CONC
Condition	COND
Connect	CONN
Constant	CONST
Construction	CONST
Contact	CONT
Continue	CONT
Corner	COR
Corporation	CORP
Correct	CORR
Corrugate	CORR
Cotter	COT
Counter	CTR
Counter Clockwise	CCW
Counterbore	CBORE
Counterdrill	CDRILL
Counterpunch	CPUNCH
Countersink	CSK
Coupling	CPLG
Cover	COV
Cross Section	XSECT
Cubic	CU
Cubic Foot	CU FT
Cubic Inch	CU IN.
Current	CUR
Customer	CUST
Cyanide	CYN

D

Decimal	DEC
Dedendum	DED
Deflect	DEFL
Degree	(°) DEG
Density	D
Department	DEPT
Design	DSGN
Detail	DET
Develop	DEV
Diagonal	DIAG
Diagram	DIAG
Diameter	DIA
Diametral Pitch	DP
Dimension	DIM.
Discharge	DISCH
Distance	DIST
Division	DIV
Double	DBL
Dovetail	DVTL
Dowel	DWL
Down	DN
Dozen	DOZ
Drafting	DFTG
Draftsman	DFTSMN
Drawing	DWG
Drill	DR
Drive	DR
Drive Fit	DF
Drop	D
Drop Forge	DF
Duplicate	DUP

E

Each	EA
East	E
Eccentric	ECC
Effective	EFF
Elbow	ELL
Electric	ELEC
Elementary	ELEM
Elevate	ELEV
Elevation	EL
Engine	ENG
Engineer	ENGR
Engineering	ENGRG
Entrance	ENT
Equal	EQ
Equation	EQ
Equipment	EQUIP
Equivalent	EQUIV
Estimate	EST
Exchange	EXCH
Exhaust	EXH
Existing	EXIST.
Exterior	EXT
Extra Heavy	X HVY
Extra Strong	X STR
Extrude	EXTR

F

Fabricate	FAB
Face to Face	F to F
Fahrenheit	F
Far Side	FS
Federal	FED.
Feed	FD
Feet	(') FT
Figure	FIG.
Fillet	FIL
Fillister	FIL
Finish	FIN.
Finish All Over	FAO
Flange	FLG
Flat	F
Flat Head	FH
Floor	FL
Fluid	FL
Focus	FOC
Foot	(') FT
Force	F
Forged Steel	FST
Forging	FORG
Forward	FWD
Foundry	FDRY
Frequency	FREQ
Front	FR
Furnish	FURN

G

Gage or Gauge	GA
Gallon	GAL
Galvanize	GALV
Galvanized Iron	GI
Galvanized Steel	GS
Gasket	GSKT
General	GEN
Glass	GL
Government	GOVT
Governor	GOV

APPENDIX 2 (CON'T)

Grade	GR
Graduation	GRAD
Graphite	GPH
Grind	GRD
Groove	GRV
Ground	GRD

H

Half-Round	½ RD
Handle	HDL
Hanger	HGR
Hard	H
Harden	HDN
Hardware	HDW
Head	HD
Headless	HDLS
Heat	HT
Heat Treat	HT TR
Heavy	HVY
Hexagon	HEX
High-Pressure	HP
High-Speed	HS
Horizontal	HOR
Horsepower	HP
Hot Rolled	HR
Hot Rolled Steel	HRS
Hour	HR
Housing	HSG
Hydraulic	HYD

I

Illustrate	ILLUS
Inboard	INBD
Inch	(") IN.
Inches per Second	IPS
Inclosure	INCL
Include	INCL
Inside Diameter	ID
Instrument	INST
Interior	INT
Internal	INT
Intersect	INT
Iron	I
Irregular	IRREG

J

Joint	JT
Joint Army-Navy	JAN
Journal	JNL
Junction	JCT

K

Key	K
Keyseat	KST
Keyway	KWY

L

Laboratory	LAB
Laminate	LAM
Lateral	LAT
Left	L
Left Hand	LH
Length	LG
Length Over All	LOA
Letter	LTR
Light	LT
Line	L
Locate	LOC
Logarithm	LOG.
Long	LG
Lubricate	LUB
Lumber	LBR

M

Machine	MACH
Machine Steel	MS
Maintenance	MAINT
Malleable	MALL
Malleable Iron	MI
Manual	MAN.
Manufacture	MFR
Manufactured	MFD
Manufacturing	MFG
Material	MATL
Maximum	MAX
Mechanical	MECH
Mechanism	MECH
Median	MED
Metal	MET.
Meter	M
Miles	MI
Miles per Hour	MPH
Millimeter	MM
Minimum	MIN
Minute	(') MIN
Miscellaneous	MISC
Month	MO
Morse Taper	MOR T
Motor	MOT
Mounted	MTD
Mounting	MTG
Multiple	MULT
Music Wire Gage	MWG

N

National	NATL
Natural	NAT
Near Face	NF
Near Side	NS
Negative	NEG
Neutral	NEUT
Nominal	NOM
Normal	NOR
North	N
Not to Scale	NTS
Number	NO.

O

Obsolete	OBS
Octagon	OCT
Office	OFF.
On Center	OC
Opposite	OPP
Optical	OPT
Original	ORIG
Outlet	OUT.
Outside Diameter	OD
Outside Face	OF
Outside Radius	OR
Overall	OA

P

Pack	PK
Packing	PKG
Page	P
Paragraph	PAR.
Part	PT
Patent	PAT.
Pattern	PATT
Permanent	PERM
Perpendicular	PERP
Piece	PC
Piece Mark	PC MK
Pint	PT
Pitch	P
Pitch Circle	PC
Pitch Diameter	PD
Plate	PL
Plumbing	PLMB
Point	PT
Point of Curve	PC
Point of Intersection	PI
Point of Tangent	PT
Polish	POL
Position	POS
Potential	POT.

APPENDIX 2 (CON'T)

Pound	LB
Pounds per Square Inch	PSI
Power	PWR
Prefabricated	PREFAB
Preferred	PFD
Prepare	PREP
Pressure	PRESS.
Process	PROC
Production	PROD
Profile	PF
Propeller	PROP
Publication	PUB
Push Button	PB

Q

Quadrant	QUAD
Quality	QUAL
Quarter	QTR

R

Radial	RAD
Radius	R
Railroad	RR
Ream	RM
Received	RECD
Record	REC
Rectangle	RECT
Reduce	RED.
Reference Line	REF L
Reinforce	REINF
Release	REL
Relief	REL
Remove	REM
Require	REQ
Required	REQD
Return	RET.
Reverse	REV
Revolution	REV
Revolutions per Minute	RPM
Right	R
Right Hand	RH
Rivet	RIV
Rockwell Hardness	RH
Roller Bearing	RB
Room	RM
Root Diameter	RD
Root Mean Square	RMS
Rough	RGH
Round	RD

S

Schedule	SCH
Schematic	SCHEM
Scleroscope Hardness	SH
Screw	SCR
Second	SEC
Section	SECT
Semi-Steel	SS
Separate	SEP
Set Screw	SS
Shaft	SFT
Sheet	SH
Shoulder	SHLD
Side	S
Single	S
Sketch	SK
Sleeve	SLV
Slide	SL
Slotted	SLOT.
Small	SM
Socket	SOC
Space	SP
Special	SPL
Specific	SP
Spot Faced	SF
Spring	SPG
Square	SQ
Standard	STD
Station	STA
Stationary	STA
Steel	STL
Stock	STK
Straight	STR
Stree	ST
Structural	STR
Substitute	SUB
Summary	SUM.
Support	SUP.
Surface	SUR
Symbol	SYM
System	SYS

T

Tangent	TAN.
Taper	TPR
Technical	TECH
Template	TEMP
Tension	TENS.
Terminal	TERM.
Thick	THK
Thousand	M
Thread	THD
Threads per Inch	TPI
Through	THRU
Time	T
Tolerance	TOL
Tongue & Groove	T & G
Tool Steel	TS
Tooth	T
Total	TOT
Transfer	TRANS
Typical	TYP

U

Ultimate	ULT
Unit	U
Universal	UNIV

V

Vacuum	VAC
Valve	V
Variable	VAR
Versus	VS
Vertical	VERT
Volt	V
Volume	VOL

W

Wall	W
Washer	WASH.
Watt	W
Week	WK
Weight	WT
West	W
Width	W
Wood	WD
Woodruff	WDF
Working Point	WP
Working Pressure	WP
Wrought	WRT
Wrought Iron	WI

X, Y, Z

Yard	YD
Year	YR

APPENDIX 3

RUNNING AND SLIDING FITS[1]

Limits are in thousandths of an inch.

Limits for hole and shaft are applied algebraically to the basic size to obtain the limits of size for the parts.

Symbols H5, g5, etc., are Hole and Shaft designations used in ABC System.

Nominal Size Range Inches	CLASS RC 1			CLASS RC 2			CLASS RC 3			CLASS RC 4		
	Limits of Clearance	Standard Limits		Limits of Clearance	Standard Limits		Limits of Clearance	Standard Limits		Limits of Clearance	Standard Limits	
Over To		Hole H5	Shaft g4		Hole H6	Shaft g5		Hole H6	Shaft f6		Hole H7	Shaft f7
0.04– 0.12	0.1 0.45	+0.2 0	−0.1 −0.25	0.1 0.55	+0.25 0	−0.1 +0.3	0.3 0.8	+0.25 0	−0.3 −0.55	0.3 1.1	+0.4 0	−0.3 −0.7
0.12– 0.24	0.15 0.5	+0.2 0	−0.15 −0.3	0.15 0.65	+0.3 0	−0.15 −0.35	0.4 1.0	+0.3 0	−0.4 −0.7	0.4 1.4	+0.5 0	−0.4 −0.9
0.24– 0.40	0.2 0.6	+0.25 0	−0.2 −0.35	0.2 0.85	+0.4 0	−0.2 −0.45	0.5 1.3	+0.4 0	−0.5 −0.9	0.5 1.7	+0.6 0	−0.5 −1.1
0.40– 0.71	0.25 0.75	+0.3 0	−0.25 −0.45	0.25 0.95	+0.4 0	−0.25 −0.55	0.6 1.4	+0.4 0	−0.6 −1.0	0.6 2.0	+0.7 0	−0.6 −1.3
0.71– 1.19	0.3 0.95	+0.4 0	−0.3 −0.55	0.3 1.2	+0.5 0	−0.3 −0.7	0.8 1.8	+0.5 0	−0.8 −1.3	0.8 2.4	+0.8 0	−0.8 −1.6
1.19– 1.97	0.4 1.1	+0.4 0	−0.4 −0.7	0.4 1.4	+0.6 0	−0.4 −0.8	1.0 2.2	+0.6 0	−1.0 −1.6	1.0 3.0	+1.0 0	−1.0 −2.0
1.97– 3.15	0.4 1.2	+0.5 0	−0.4 −0.7	0.4 1.6	+0.7 0	−0.4 −0.9	1.2 2.6	+0.7 0	−1.2 −1.9	1.2 3.6	+1.2 0	−1.2 −2.4
3.15– 4.73	0.5 1.5	+0.6 0	−0.5 −0.9	0.5 2.0	+0.9 0	−0.5 −1.1	1.4 3.2	+0.9 0	−1.4 −2.3	1.4 4.2	+1.4 0	−1.4 −2.8
4.73– 7.09	0.6 1.8	+0.7 0	−0.6 −1.1	0.6 2.3	+1.0 0	−0.6 −1.3	1.6 3.6	+1.0 0	−1.6 −2.6	1.6 4.8	+1.6 0	−1.6 −3.2
7.09– 9.85	0.6 2.0	+0.8 0	−0.6 −1.2	0.6 2.6	+1.2 0	−0.6 −1.4	2.0 4.4	+1.2 0	−2.0 −3.2	2.0 5.6	+1.8 0	−2.0 −3.8
9.85–12.41	0.8 2.3	+0.9 0	−0.8 −1.4	0.8 2.9	+1.2 0	−0.8 −1.7	2.5 4.9	+1.2 0	−2.5 −3.7	2.5 6.5	+2.0 0	−2.5 −4.5
12.41–15.75	1.0 2.7	+1.0 0	−1.0 −1.7	1.0 3.4	+1.4 0	−1.0 −2.0	3.0 5.8	+1.4 0	−3.0 −4.4	3.0 7.4	+2.2 0	−3.0 −5.2

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[1] From ASA B4.1-1955. For larger diameters, see the standard.

APPENDIX 3 (CON'T)

RUNNING AND SLIDING FITS

Nominal Size Range Inches	CLASS RC 5			CLASS RC 6			CLASS RC 7			CLASS RC 8			CLASS RC 9		
	Limits of Clearance	Standard Limits		Limits of Clearance	Standard Limits		Limits of Clearance	Standard Limits		Limits of Clearance	Standard Limits		Limits of Clearance	Standard Limits	
Over To		Hole H7	Shaft e7		Hole H8	Shaft e8		Hole H9	Shaft d8		Hole H10	Shaft c9		Hole H11	Shaft
0.04– 0.12	0.6 1.4	+0.4 0	−0.6 −1.0	0.6 1.8	+0.6 0	−0.6 −1.2	1.0 2.6	+1.0 0	− 1.0 − 1.6	2.5 5.1	+1.6 0	− 2.5 − 3.5	4.0 8.1	+ 2.5 0	− 4.0 − 5.6
0.12– 0.24	0.8 1.8	+0.5 0	−0.8 −1.3	0.8 2.2	+0.7 0	−0.8 −1.5	1.2 3.1	+1.2 0	− 1.2 − 1.9	2.8 5.8	+1.8 0	− 2.8 − 4.0	4.5 9.0	+ 3.0 0	− 4.5 − 6.0
0.24– 0.40	1.0 2.2	+0.6 0	−1.0 −1.6	1.0 2.8	+0.9 0	−1.0 −1.9	1.6 3.9	+1.4 0	− 1.6 − 2.5	3.0 6.6	+2.2 0	− 3.0 − 4.4	5.0 10.7	+ 3.5 0	− 5.0 − 7.2
0.40– 0.71	1.2 2.6	+0.7 0	−1.2 −1.9	1.2 3.2	+1.0 0	−1.2 −2.2	2.0 4.6	+1.6 0	− 2.0 − 3.0	3.5 7.9	+2.8 0	− 3.5 − 5.1	6.0 12.8	+ 4.0 0	− 6.0 − 8.8
0.71– 1.19	1.6 3.2	+0.8 0	−1.6 −2.4	1.6 4.0	+1.2 0	−1.6 −2.8	2.5 5.7	+2.0 0	− 2.5 − 3.7	4.5 10.0	+3.5 0	− 4.5 − 6.5	7.0 15.5	+ 5.0 0	− 7.0 −10.5
1.19– 1.97	2.0 4.0	+1.0 0	−2.0 −3.0	2.0 5.2	+1.6 0	−2.0 −3.6	3.0 7.1	+2.5 0	− 3.0 − 4.6	5.0 11.5	+4.0 0	− 5.0 − 7.5	8.0 18.0	+ 6.0 0	− 8.0 −12.0
1.97– 3.15	2.5 4.9	+1.2 0	−2.5 −3.7	2.5 6.1	+1.8 0	−2.5 −4.3	4.0 8.8	+3.0 0	− 4.0 − 5.8	6.0 13.5	+4.5 0	− 6.0 − 9.0	9.0 20.5	+ 7.0 0	− 9.0 −13.5
3.15– 4.73	3.0 5.8	+1.4 0	−3.0 −4.4	3.0 7.4	+2.2 0	−3.0 −5.2	5.0 10.7	+3.5 0	− 5.0 − 7.2	7.0 15.5	+5.0 0	− 7.0 −10.5	10.0 24.0	+ 9.0 0	−10.0 −15.0
4.73– 7.09	3.5 6.7	+1.6 0	−3.5 −5.1	3.5 8.5	+2.5 0	−3.5 −6.0	6.0 12.5	+4.0 0	− 6.0 − 8.5	8.0 18.0	+6.0 0	− 8.0 −12.0	12.0 28.0	+10.0 0	−12.0 −18.0
7.09– 9.85	4.0 7.6	+1.8 0	−4.0 −5.8	4.0 9.6	+2.8 0	−4.0 −6.8	7.0 14.3	+4.5 0	− 7.0 − 9.8	10.0 21.5	+7.0 0	−10.0 −14.5	15.0 34.0	+12.0 0	−15.0 −22.0
9.85–12.41	5.0 9.0	+2.0 0	−5.0 −7.0	5.0 11.0	+3.0 0	−5.0 −8.0	8.0 16.0	+5.0 0	− 8.0 −11.0	12.0 25.0	+8.0 0	−12.0 −17.0	18.0 38.0	+12.0 0	−18.0 −26.0
12.41–15.75	6.0 10.4	+2.2 0	−6.0 −8.2	6.0 13.0	+3.5 0	−6.0 −9.5	10.0 19.5	+6.0 0	−10.0 −13.5	14.0 29.0	+9.0 0	−14.0 −20.0	22.0 45.0	+14.0 0	−22.0 −31.0

[1] From ASA B4.1–1955. For larger diameters, see the standard.

APPENDIX 4

CLEARANCE LOCATIONAL FITS[1]

Limits are in thousandths of an inch.

Limits for hole and shaft are applied algebraically to the basic size to obtain the limits of size for the parts.

Symbols H6, h5, etc., are Hole and Shaft designations used in ABC System.

Nominal Size Range Inches	CLASS LC 1			CLASS LC 2			CLASS LC 3			CLASS LC 4			CLASS LC 5		
	Limits of Clearance	Standard Limits		Limits of Clearance	Standard Limits		Limits of Clearance	Standard Limits		Limits of Clearance	Standard Limits		Limits of Clearance	Standard Limits	
Over To		Hole H6	Shaft h5		Hole H7	Shaft h6		Hole H8	Shaft h7		Hole H9	Shaft h9		Hole H7	Shaft g6
0.04– 0.12	0 0.45	+0.25 − 0	+ 0 −0.2	0 0.65	+0.4 − 0	+ 0 −0.25	0 1	+0.6 − 0	+ 0 −0.4	0 2.0	+1.0 − 0	+ 0 −1.0	0.1 0.75	+0.4 − 0	−0.1 −0.35
0.12– 0.24	0 0.5	+0.3 − 0	+ 0 −0.2	0 0.8	+0.5 − 0	+ 0 −0.3	0 1.2	+0.7 − 0	+ 0 −0.5	0 2.4	+1.2 − 0	+ 0 +1.2	0.15 0.95	+0.5 − 0	−0.15 −0.45
0.24– 0.40	0 0.65	+0.4 − 0	+ 0 −0.25	0 1.0	+0.6 − 0	+ 0 −0.4	0 1.5	+0.9 − 0	+ 0 −0.6	0 2.8	+1.4 − 0	+ 0 −1.4	0.2 1.2	+0.6 − 0	−0.2 −0.6
0.40– 0.71	0 0.7	+0.4 − 0	+ 0 −0.3	0 1.1	+0.7 − 0	+ 0 −0.4	0 1.7	+1.0 − 0	+ 0 −0.7	0 3.2	+1.6 − 0	+ 0 −1.6	0.25 1.35	+0.7 − 0	−0.25 −0.65
0.71– 1.19	0 0.9	+0.5 − 0	+ 0 −0.4	0 1.3	+0.8 − 0	+ 0 −0.5	0 2	+1.2 − 0	+ 0 −0.8	0 4	+2.0 − 0	+ 0 −2.0	0.3 1.6	+0.8 − 0	−0.3 −0.8
1.19– 1.97	0 1.0	+0.6 − 0	+ 0 −0.4	0 1.6	+1.0 − 0	+ 0 −0.6	0 2.6	+1.6 − 0	+ 0 −1	0 5	+2.5 − 0	+ 0 −2.5	0.4 2.0	+1.0 − 0	−0.4 −1.0
1.97– 3.15	0 1.2	+0.7 − 0	+ 0 −0.5	0 1.9	+1.2 − 0	+ 0 −0.7	0 3	+1.8 − 0	+ 0 −1.2	0 6	+ 3 − 0	+ 0 −3	0.4 2.3	+1.2 − 0	−0.4 −1.1
3.15– 4.73	0 1.5	+0.9 − 0	+ 0 −0.6	0 2.3	+1.4 − 0	+ 0 −0.9	0 3.6	+2.2 − 0	+ 0 −1.4	0 7	+3.5 − 0	+ 0 −3.5	0.5 2.8	+1.4 − 0	−0.5 −1.4
4.73– 7.09	0 1.7	+1.0 − 0	+ 0 −0.7	0 2.6	+1.6 − 0	+ 0 −1.0	0 4.1	+2.5 − 0	+ 0 −1.6	0 8	+4 − 0	+ 0 −4	0.6 3.2	+1.6 − 0	−0.6 −1.6
7.09– 9.85	0 2.0	+1.2 − 0	+ 0 −0.8	0 3.0	+1.8 − 0	+ 0 −1.2	0 4.6	+2.8 − 0	+ 0 −1.8	0 9	+4.5 − 0	+ 0 −4.5	0.6 3.6	+1.8 − 0	−0.6 −1.8
9.85–12.41	0 2.1	+1.2 − 0	+ 0 −0.9	0 3.2	+2.0 − 0	+ 0 −1.2	0 5	+3.0 − 0	+ 0 −2.0	0 10	+5 − 0	+ 0 −5	0.7 3.9	+2.0 − 0	−0.7 −1.9
12.41–15.75	0 2.4	+1.4 − 0	+ 0 −1.0	0 3.6	+2.2 − 0	+ 0 −1.4	0 5.7	+3.5 − 0	+ 0 −2.2	0 12	+6 − 0	+ 0 −6	0.7 4.3	+2.2 − 0	−0.7 −2.1

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[1] From ASA B4.1–1955. For larger diameters, see the standard.

APPENDIX 4 (CON'T)

CLEARANCE LOCATIONAL FITS (continued)[1]

Nominal Size Range Inches	CLASS LC 6			CLASS LC 7			CLASS LC 8			CLASS LC 9			CLASS LC 10			CLASS LC 11		
	Limits of Clearance	Standard Limits		Limits of Clearance	Standard Limits		Limits of Clearance	Standard Limits		Limits of Clearance	Standard Limits		Limits of Clearance	Standard Limits		Limits of Clearance	Standard Limits	
Over To		Hole H8	Shaft f8		Hole H9	Shaft e9		Hole H10	Shaft d9		Hole H11	Shaft c11		Hole H 12	Shaft		Hole H 13	Shaft
0.04– 0.12	0.3 1.5	+0.6 – 0	–0.3 –0.9	0.6 2.6	+1.0 – 0	–0.6 –1.6	1.0 3.6	+1.6 – 0	– 1.0 – 2.0	2.5 7.5	+2.5 – 0	–2.5 –5.0	4 12	+ 4 – 0	– 4 – 8	5 17	+ 6 – 0	– 5 – 11
0.12– 0.24	0.4 1.8	+0.7 – 0	–0.4 –1.1	0.8 3.2	+1.2 – 0	–0.8 –2.0	1.2 4.2	+1.8 – 0	– 1.2 – 2.4	2.8 8.8	+3.0 – 0	–2.8 –5.8	4.5 14.5	+ 5 – 0	–4.5 –9.5	6 20	+ 7 – 0	– 6 – 13
0.24– 0.40	0.5 2.3	+0.9 – 0	–0.5 –1.4	1.0 3.8	+1.4 – 0	–1.0 –2.4	1.6 5.2	+2.2 – 0	– 1.6 – 3.0	3.0 10.0	+3.5 – 0	–3.0 –6.5	5 17	+ 6 – 0	– 5 – 11	7 25	+ 9 – 0	– 7 – 16
0.40– 0.71	0.6 2.6	+1.0 – 0	–0.6 –1.6	1.2 4.4	+1.6 – 0	–1.2 –2.8	2.0 6.4	+2.8 – 0	– 2.0 – 3.6	3.5 11.5	+4.0 – 0	–3.5 –7.5	6 20	+ 7 – 0	– 6 – 13	8 28	+10 – 0	– 8 – 18
0.71– 1.19	0.8 3.2	+1.2 – 0	–0.8 –2.0	1.6 5.6	+2.0 – 0	–1.6 –3.6	2.5 8.0	+3.5 – 0	– 2.5 – 4.5	4.5 14.5	+5.0 – 0	–4.5 –9.5	7 23	+ 8 – 0	– 7 – 15	10 34	+12 – 0	– 10 – 22
1.19– 1.97	1.0 4.2	+1.6 – 0	–1.0 –2.6	2.0 7.0	+2.5 – 0	–2.0 –4.5	3.0 9.5	+4.0 – 0	– 3.0 – 5.5	5 17	+6 – 0	– 5 – 11	8 28	+10 – 0	– 8 – 18	12 44	+16 – 0	– 12 – 28
1.97– 3.15	1.2 4.8	+1.8 – 0	–1.2 –3.0	2.5 8.5	+3.0 – 0	–2.5 –5.5	4.0 11.5	+4.5 – 0	– 4.0 – 7.0	6 20	+7 – 0	– 6 – 13	10 34	+12 – 0	– 10 – 22	14 50	+18 – 0	– 14 – 32
3.15– 4.73	1.4 5.8	+2.2 – 0	–1.4 –3.6	3.0 10.0	+3.5 – 0	–3.0 –6.5	5.0 13.5	+5.0 – 0	– 5.0 – 8.5	7 25	+9 – 0	– 7 – 16	11 39	+14 – 0	– 11 – 25	16 60	+22 – 0	– 16 – 38
4.73– 7.09	1.6 6.6	+2.5 – 0	–1.6 –4.1	3.5 11.5	+4.0 – 0	–3.5 –7.5	6 16	+6 – 0	– 6 –10	8 28	+10 – 0	– 8 – 18	12 44	+16 – 0	– 12 – 28	18 68	+25 – 0	– 18 – 43
7.09– 9.85	2.0 7.6	+2.8 – 0	–2.0 –4.8	4.0 13.0	+4.5 – 0	–4.0 –8.5	7 18.5	+7 – 0	– 7 –11.5	10 34	+12 – 0	– 10 – 22	16 52	+18 – 0	– 16 – 34	22 78	+28 – 0	– 22 – 50
9.85–12.41	2.2 8.2	+3.0 – 0	–2.2 –5.2	4.5 14.5	+5.0 – 0	–4.5 –9.5	7 20	+8 – 0	– 7 –12	12 36	+12 – 0	– 12 – 24	20 60	+20 – 0	– 20 – 40	28 88	+30 – 0	– 28 – 58
12.41–15.75	2.5 9.5	+3.5 – 0	–2.5 –6.0	5 17	+6 – 0	– 5 –11	8 23	+9 – 0	– 8 –14	14 42	+14 – 0	– 14 – 28	22 66	+22 – 0	– 22 – 44	30 100	+35 – 0	– 30 – 65

[1] From ASA B4.1–1955. For larger diameters, see the standard.

APPENDIX 5

TRANSITION LOCATIONAL FITS[1]

Limits are in thousandths of an inch.

Limits for hole and shaft are applied algebraically to the basic size to obtain the limits of size for the mating parts.

"Fit" represents the maximum interference (minus values) and the maximum clearance (plus values).

Symbols H8, j6, etc., are Hole and Shaft designations used in ABC System.

Nominal Size Range Inches	CLASS LT 1			CLASS LT 2			CLASS LT 3			CLASS LT 4			CLASS LT 6			CLASS LT 7		
	Fit	Standard Limits		Fit	Standard Limits		Fit	Standard Limits		Fit	Standard Limits		Fit	Standard Limits		Fit	Standard Limits	
Over To		Hole H7	Shaft j6		Hole H8	Shaft j7		Hole H7	Shaft k6		Hole H8	Shaft k7		Hole H8	Shaft m7		Hole H7	Shaft n6
0.04– 0.12	−0.15 +0.5	+0.4 − 0	+0.15 −0.1	−0.3 +0.7	+0.6 − 0	+0.3 −0.1							−0.55 +0.45	+0.6 − 0	+0.55 +0.15	−0.5 +0.15	+0.4 − 0	+0.5 +0.25
0.12– 0.24	−0.2 +0.6	+0.5 − 0	+0.2 −0.1	−0.4 +0.8	+0.7 − 0	+0.4 −0.1							+0.7 +0.5	+0.7 − 0	+0.7 +0.2	−0.6 +0.2	+0.5 − 0	+0.6 +0.3
0.24– 0.40	−0.3 +0.7	+0.6 − 0	+0.3 −0.1	−0.4 +1.1	+0.9 − 0	+0.4 −0.2	−0.5 +0.5	+0.6 − 0	+0.5 +0.1	−0.7 +0.8	+0.9 − 0	+0.7 +0.1	−0.8 +0.7	+0.9 − 0	+0.8 +0.2	−0.8 +0.2	+0.6 − 0	+0.8 +0.4
0.40– 0.71	−0.3 +0.8	+0.7 − 0	+0.3 −0.1	−0.5 +1.2	+1.0 − 0	+0.5 −0.2	−0.5 +0.6	+0.7 − 0	+0.5 +0.1	−0.8 +0.9	+1.0 − 0	+0.8 +0.1	−1.0 +0.7	+1.0 − 0	+1.0 +0.3	−0.9 +0.2	+0.7 − 0	+0.9 +0.5
0.71– 1.19	−0.3 +1.0	+0.8 − 0	+0.3 −0.2	−0.5 +1.5	+1.2 − 0	+0.5 −0.3	−0.6 +0.7	+0.8 − 0	+0.6 +0.1	−0.9 +1.1	+1.2 − 0	+0.9 +0.1	−1.1 +0.9	+1.2 − 0	+1.1 +0.3	−1.1 +0.2	+0.8 − 0	+1.1 +0.6
1.19– 1.97	−0.4 +1.2	+1.0 − 0	+0.4 −0.2	−0.6 +2.0	+1.6 − 0	+0.6 −0.4	−0.7 +0.9	+1.0 − 0	+0.7 +0.1	−1.1 +1.5	+1.6 − 0	+1.1 +0.1	−1.4 +1.2	+1.6 − 0	+1.4 +0.4	−1.3 +0.3	+1.0 − 0	+1.3 +0.7
1.97– 3.15	−0.4 +1.5	+1.2 − 0	+0.4 −0.3	−0.7 +2.3	+1.8 − 0	+0.7 −0.5	−0.8 +1.1	+1.2 − 0	+0.8 +0.1	−1.3 +1.7	+1.8 − 0	+1.3 +0.1	−1.7 +1.3	+1.8 − 0	+1.7 +0.5	−1.5 +0.4	+1.2 − 0	+1.5 +0.8
3.15– 4.73	−0.5 +1.8	+1.4 − 0	+0.5 −0.4	−0.8 +2.8	+2.2 − 0	+0.8 −0.6	−1.0 +1.3	+1.4 − 0	+1.0 +0.1	−1.5 +2.1	+2.2 − 0	+1.5 +0.1	−1.9 +1.7	+2.2 − 0	+1.9 +0.5	−1.9 +0.4	+1.4 − 0	+1.9 +1.0
4.73– 7.09	−0.6 +2.0	+1.6 − 0	+0.6 −0.4	−0.9 +3.2	+2.5 − 0	+0.9 −0.7	−1.1 +1.5	+1.6 − 0	+1.1 +0.1	−1.7 +2.4	+2.5 − 0	+1.7 +0.1	−2.2 +1.9	+2.5 − 0	+2.2 +0.6	−2.2 +0.4	+1.6 − 0	+2.2 +1.2
7.09– 9.85	−0.7 +2.3	+1.8 − 0	+0.7 −0.5	−1.0 +3.6	+2.8 − 0	+1.0 −0.8	−1.4 +1.6	+1.8 − 0	+1.4 +0.2	−2.0 +2.6	+2.8 − 0	+2.0 +0.2	−2.4 +2.2	+2.8 − 0	+2.4 +0.6	−2.6 +0.4	+1.8 − 0	+2.6 +1.4
9.85–12.41	−0.7 +2.6	+2.0 − 0	+0.7 −0.6	−1.0 +4.0	+3.0 − 0	+1.0 −1.0	−1.4 +1.8	+2.0 − 0	+1.4 +0.2	−2.2 +2.8	+3.0 − 0	+2.2 +0.2	−2.8 +2.2	+3.0 − 0	+2.8 +0.8	−2.6 +0.6	+2.0 − 0	+2.6 +1.4
12.41–15.75	−0.7 +2.9	+2.2 − 0	+0.7 −0.7	−1.2 +4.5	+3.5 + 0	+1.2 −1.0	−1.6 +2.0	+2.2 − 0	+1.6 +0.2	−2.4 +3.3	+3.5 − 0	+2.4 +0.2	−3.0 +2.7	+3.5 − 0	+3.0 +0.8	−3.0 +0.6	+2.2 − 0	+3.0 +1.6

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[1] From ASA B4.1–1955. For larger diameters, see the standard.

APPENDIX 6

INTERFERENCE LOCATIONAL FITS[1]

Limits are in thousandths of an inch.

Limits for hole and shaft are applied algebraically to the basic size to obtain the limits of size for the parts.

Symbols H7, p6, etc., are Hole and Shaft designations used in ABC System.

Nominal Size Range Inches	Class LN 2			Class LN 3			Nominal Size Range Inches	Class LN 2			Class LN 3		
	Limits of Interference	Standard Limits		Limits of Interference	Standard Limits			Limits of Interference	Standard Limits		Limits of Interference	Standard Limits	
Over To		Hole H7	Shaft p6		Hole H7	Shaft r6	Over To		Hole H7	Shaft p6		Hole H7	Shaft r6
0.04–0.12	0 0.65	+0.4 − 0	+0.65 +0.4	0.1 0.75	+0.4 − 0	+0.75 +0.5	1.97– 3.15	0.2 2.1	+1.2 − 0	+2.1 +1.4	0.4 2.3	+1.2 − 0	+2.3 +1.6
0.12–0.24	0 0.8	+0.5 − 0	+0.8 +0.5	0.1 0.9	+0.5 − 0	+0.9 +0.6	3.15– 4.73	0.2 2.5	+1.4 − 0	+2.5 +1.6	0.6 2.9	+1.4 − 0	+2.9 +2.0
0.24–0.40	0 1.0	+0.6 − 0	+1.0 +0.6	0.2 1.2	+0.6 − 0	+1.2 +0.8	4.73– 7.09	0.2 2.8	+1.6 − 0	+2.8 +1.8	0.9 3.5	+1.6 − 0	+3.5 +2.5
0.40–0.71	0 1.1	+0.7 − 0	+1.1 +0.7	0.3 1.4	+0.7 − 0	+1.4 +1.0	7.09– 9.85	0.2 3.2	+1.8 − 0	+3.2 +2.0	1.2 4.2	+1.8 − 0	+4.2 +3.0
0.71–1.19	0 1.3	+0.8 − 0	+1.3 +0.8	0.4 1.7	+0.8 − 0	+1.7 +1.2	9.85–12.41	0.2 3.4	+2.0 − 0	+3.4 +2.2	1.5 4.7	+2.0 − 0	+4.7 +3.5
1.19–1.97	0 1.6	+1.0 − 0	+1.6 +1.0	0.4 2.0	+1.0 − 0	+2.0 +1.4	12.41 15.75	0.3 3.9	+2.2 − 0	+3.9 +2.5	2.3 5.9	+2.2 − 0	+5.9 +4.5

[1] From ASA B4.1–1955. For larger diameters, see the standard.

APPENDIX 7

FORCE AND SHRINK FITS[1]

Limits are in thousandths of an inch.
Limits for hole and shaft are applied algebraically to the basic size to obtain the limits of size for the parts.
Symbols H7, s6, etc., are Hole and Shaft designations used in ABC System (Appendix I).

Nominal Size Range Inches	CLASS FN 1			CLASS FN 2			CLASS FN 3			CLASS FN 4			CLASS FN 5		
Over To	Limits of Interference	Standard Limits Hole H6	Standard Limits Shaft	Limits of Interference	Standard Limits Hole H7	Standard Limits Shaft s6	Limits of Interference	Standard Limits Hole H7	Standard Limits Shaft t6	Limits of Interference	Standard Limits Hole H7	Standard Limits Shaft u6	Limits of Interference	Standard Limits Hole H7	Standard Limits Shaft x7
0.04– 0.12	0.05 0.5	+0.25 – 0	+0.5 +0.3	0.2 0.85	+0.4 – 0	+0.85 +0.6				0.3 0.95	+0.4 – 0	+ 0.95 + 0.7	0.5 1.3	+0.4 – 0	+ 1.3 + 0.9
0.12– 0.24	0.1 0.6	+0.3 – 0	+0.6 +0.4	0.2 1.0	+0.5 – 0	+1.0 +0.7				0.4 1.2	+0.5 – 0	+ 1.2 + 0.9	0.7 1.7	+0.5 – 0	+ 1.7 + 1.2
0.24– 0.40	0.1 0.75	+0.4 – 0	+0.75 +0.5	0.4 1.4	+0.6 – 0	+1.4 +1.0				0.6 1.6	+0.6 – 0	+ 1.6 + 1.2	0.8 2.0	+0.6 – 0	+ 2.0 + 1.4
0.40– 0.56	0.1 0.8	+0.4 – 0	+0.8 +0.5	0.5 1.6	+0.7 – 0	+1.6 +1.2				0.7 1.8	+0.7 – 0	+ 1.8 + 1.4	0.9 2.3	+0.7 – 0	+ 2.3 + 1.6
0.56– 0.71	0.2 0.9	+0.4 – 0	+0.9 +0.6	0.5 1.6	+0.7 – 0	+1.6 +1.2				0.7 1.8	+0.7 – 0	+ 1.8 + 1.4	1.1 2.5	+0.7 – 0	+ 2.5 + 1.8
0.71– 0.95	0.2 1.1	+0.5 – 0	+1.1 +0.7	0.6 1.9	+0.8 – 0	+1.9 +1.4				0.8 2.1	+0.8 – 0	+ 2.1 + 1.6	1.4 3.0	+0.8 – 0	+ 3.0 + 2.2
0.95– 1.19	0.3 1.2	+0.5 – 0	+1.2 +0.8	0.6 1.9	+0.8 – 0	+1.9 +1.4	0.8 2.1	+0.8 – 0	+ 2.1 + 1.6	1.0 2.3	+0.8 – 0	+ 2.3 + 1.8	1.7 3.3	+0.8 – 0	+ 3.3 + 2.5
1.19– 1.58	0.3 1.3	+0.6 – 0	+1.3 +0.9	0.8 2.4	+1.0 – 0	+2.4 +1.8	1.0 2.6	+1.0 – 0	+ 2.6 + 2.0	1.5 3.1	+1.0 – 0	+ 3.1 + 2.5	2.0 4.0	+1.0 – 0	+ 4.0 + 3.0
1.58– 1.97	0.4 1.4	+0.6 – 0	+1.4 +1.0	0.8 2.4	+1.0 – 0	+2.4 +1.8	1.2 2.8	+1.0 – 0	+ 2.8 + 2.2	1.8 3.4	+1.0 – 0	+ 3.4 + 2.8	3.0 5.0	+1.0 – 0	+ 5.0 + 4.0
1.97– 2.56	0.6 1.8	+0.7 – 0	+1.8 +1.3	0.8 2.7	+1.2 – 0	+2.7 +2.0	1.3 3.2	+1.2 – 0	+ 3.2 + 2.5	2.3 4.2	+1.2 – 0	+ 4.2 + 3.5	3.8 6.2	+1.2 – 0	+ 6.2 + 5.0
2.56– 3.15	0.7 1.9	+0.7 – 0	+1.9 +1.4	1.0 2.9	+1.2 – 0	+2.9 +2.2	1.8 3.7	+1.2 – 0	+ 3.7 + 3.0	2.8 4.7	+1.2 – 0	+ 4.7 + 4.0	4.8 7.2	+1.2 – 0	+ 7.2 + 6.0
3.15– 3.94	0.9 2.4	+0.9 – 0	+2.4 +1.8	1.4 3.7	+1.4 – 0	+3.7 +2.8	2.1 4.4	+1.4 – 0	+ 4.4 + 3.5	3.6 5.9	+1.4 – 0	+ 5.9 + 5.0	5.6 8.4	+1.4 – 0	+ 8.4 + 7.0
3.94– 4.73	1.1 2.6	+0.9 – 0	+2.6 +2.0	1.6 3.9	+1.4 – 0	+3.9 +3.0	2.6 4.9	+1.4 – 0	+ 4.9 + 4.0	4.6 6.9	+1.4 – 0	+ 6.9 + 6.0	6.6 9.4	+1.4 – 0	+ 9.4 + 8.0
4.73– 5.52	1.2 2.9	+1.0 – 0	+2.9 +2.2	1.9 4.5	+1.6 – 0	+4.5 +3.5	3.4 6.0	+1.6 – 0	+ 6.0 + 5.0	5.4 8.0	+1.6 – 0	+ 8.0 + 7.0	8.4 11.6	+1.6 – 0	+11.6 +10.0
5.52– 6.30	1.5 3.2	+1.0 – 0	+3.2 +2.5	2.4 5.0	+1.6 – 0	+5.0 +4.0	3.4 6.0	+1.6 – 0	+ 6.0 + 5.0	5.4 8.0	+1.6 – 0	+ 8.0 + 7.0	10.4 13.6	+1.6 – 0	+13.6 +12.0
6.30– 7.09	1.8 3.5	+1.0 – 0	+3.5 +2.8	2.9 5.5	+1.6 – 0	+5.5 +4.5	4.4 7.0	+1.6 – 0	+ 7.0 + 6.0	6.4 9.0	+1.6 – 0	+ 9.0 + 8.0	10.4 13.6	+1.6 – 0	+13.6 +12.0
7.09– 7.88	1.8 3.8	+1.2 – 0	+3.8 +3.0	3.2 6.2	+1.8 – 0	+6.2 +5.0	5.2 8.2	+1.8 – 0	+ 8.2 + 7.0	7.2 10.2	+1.8 – 0	+10.2 + 9.0	12.2 15.8	+1.8 – 0	+15.8 +14.0
7.88– 8.86	2.3 4.3	+1.2 – 0	+4.3 +3.5	3.2 6.2	+1.8 – 0	+6.2 +5.0	5.2 8.2	+1.8 – 0	+ 8.2 + 7.0	8.2 11.2	+1.8 – 0	+11.2 +10.0	14.2 17.8	+1.8 – 0	+17.8 +16.0
8.86– 9.85	2.3 4.3	+1.2 – 0	+4.3 +3.5	4.2 7.2	+1.8 – 0	+7.2 +6.0	6.2 9.2	+1.8 – 0	+ 9.2 + 8.0	10.2 13.2	+1.8 – 0	+13.2 +12.0	14.2 17.8	+1.8 – 0	+17.8 +16.0
9.85–11.03	2.8 4.9	+1.2 – 0	+4.9 +4.0	4.0 7.2	+2.0 – 0	+7.2 +6.0	7.0 10.2	+2.0 – 0	+10.2 + 9.0	10.2 13.2	+2.0 – 0	+13.2 +12.0	16.0 20.0	+2.0 – 0	+20.0 +18.0
11.03–12.41	2.8 4.9	+1.2 – 0	+4.9 +4.0	5.0 8.2	+2.0 – 0	+8.2 +7.0	7.0 10.2	+2.0 – 0	+10.2 + 9.0	12.0 15.2	+2.0 – 0	+15.2 +14.0	18.0 22.0	+2.0 – 0	+22.0 +20.0
12.41–13.98	3.1 5.5	+1.4 – 0	+5.5 +4.5	5.8 9.4	+2.2 – 0	+9.4 +8.0	7.8 11.4	+2.2 – 0	+11.4 +10.0	13.8 17.4	+2.2 – 0	+17.4 +16.0	19.8 24.2	+2.2 – 0	+24.2 +22.0

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[1] From ASA B4.1–1955. For larger diameters, see the standard.

APPENDIX 8

AMERICAN STANDARD UNIFIED AND AMERICAN THREADS[1]

Nominal Diameter	Coarse[2] NC UNC		Fine[2] NF UNF		Extra Fine[3] NEF UNEF		Nominal Diameter	Coarse[2] NC UNC		Fine[2] NF UNF		Extra Fine[3] NEF UNEF	
	Thds. per in.	Tap Drill[4]	Thds. per in.	Tap Drill[4]	Thds. per in.	Tap Drill[4]		Thds. per in.	Tap Drill[4]	Thds. per in.	Tap Drill[4]	Thds. per in.	Tap Drill[4]
0 (.060)			80	3/64			1	**8**	7/8	**12**	59/64	**20**	61/64
1 (.073)	64	No. 53	72	No. 53			1 1/16					18	1
2 (.086)	56	No. 50	64	No. 50			1 1/8	**7**	63/64	**12**	1 3/64	18	1 5/64
3 (.099)	48	No. 47	56	No. 45			1 3/16					18	1 9/64
4 (.112)	40	No. 43	48	No. 42			1 1/4	**7**	1 7/64	**12**	1 11/64	18	1 3/16
5 (.125)	40	No. 38	44	No. 37			1 5/16					18	1 17/64
6 (.138)	32	No. 36	40	No. 33			1 3/8	**6**	1 7/32	**12**	1 19/64	18	1 5/16
8 (.164)	32	No. 29	36	No. 29			1 7/16					18	1 3/8
10 (.190)	24	No. 25	32	No. 21			1 1/2	**6**	1 11/32	**12**	1 27/64	18	1 7/16
12 (.216)	24	No. 16	28	No. 14	32	No. 13	1 9/16					18	1 1/2
1/4	**20**	No. 7	**28**	No. 3	32	7/32	1 5/8					18	1 9/16
5/16	**18**	F	**24**	I	32	9/32	1 11/16					18	1 5/8
3/8	**16**	5/16	**24**	Q	32	11/32	1 3/4	**5**	1 9/16			**16**	1 11/16
7/16	**14**	U	**20**	25/64	28	13/32	2	**4 1/2**	1 25/32			**16**	1 15/16
1/2	13*	27/64	**20**	29/64	28	15/32	2 1/4	**4 1/2**	2 1/32				
1/2	**12**	27/64											
9/16	**12**	31/64	**18**	33/64	24	33/64	2 1/2	**4**	2 1/4				
5/8	**11**	17/32	**18**	37/64	24	37/64	2 3/4	**4**	2 1/2				
11/16					24	41/64	3	**4**	2 3/4				
3/4	**10**	21/32	**16**	11/16	**20**	45/64	3 1/4	**4**					
13/16					**20**	49/64	3 1/2	**4**					
7/8	**9**	49/64	**14**	13/16	**20**	53/64	3 3/4	**4**					
15/16					**20**	57/64	4	**4**					

[1] ASA B1.1–1949. Bold type indicates Unified threads.

[2] Classes 1A, 2A, 3A, 1B, 2B, 3B, 2, and 3. [3] Classes 2A, 2B, 2, and 3.

[4] For approximate 75% full depth of thread.

*The ½" Coarse thread with 13 threads per inch is optional American Standard, but is not Unified.

APPENDIX 8 (CON'T)

AMERICAN STANDARD UNIFIED AND AMERICAN THREADS[1]

NOMINAL DIAMETER	8-PITCH SERIES 8N		12-PITCH SERIES 12N and 12UN		16-PITCH SERIES 16 N and 16UN		NOMINAL DIAMETER	8-PITCH SERIES		12-PITCH SERIES		16-PITCH SERIES	
	Thds. per in.	Tap Drill[2]	Thds. per in.	Tap Drill[2]	Thds. per in.	Tap Drill[2]		Thds. per in.	Tap Drill[2]	Thds. per in.	Tap Drill[2]	Thds. per in.	Tap Drill[2]
1/2			**12**	27/64			2 1/16					16	2
9/16			**12**	31/64			2 1/8	8	2	**12**	2 3/64	16	2 1/16
5/8			**12**	35/64			2 3/16					16	2 1/8
11/16			**12**	39/64			2 1/4	8	2 1/8	**12**	2 11/64	**16**	2 3/16
3/4			**12**	43/64	**16**	11/16	2 5/16					16	2 1/4
13/16			**12**	47/64	**16**	3/4	2 3/8			12	2 19/64	16	2 5/16
7/8			**12**	51/64	**16**	13/16	2 7/16					16	2 3/8
15/16			**12**	55/64	**16**	7/8	2 1/2	8	2 3/8	**12**	2 27/64	**16**	2 7/16
1	8	7/8	**12**	59/64	**16**	15/16	2 5/8			12	2 35/64	16	2 9/16
1 1/16			**12**	63/64	**16**	1	2 3/4	8	2 5/8	**12**	2 43/64	**16**	2 11/16
1 1/8	8	1	**12**	1 3/64	**16**	1 1/16	2 7/8			12		16	
1 3/16			**12**	1 7/64	**16**	1 1/8	3	8	2 7/8	**12**		**16**	
1 1/4	8	1 1/8	**12**	1 11/64	**16**	1 3/16	3 1/8			12		16	
1 5/16			**12**	1 15/64	**16**	1 1/4	3 1/4	8		**12**		**16**	
1 3/8	8	1 1/4	**12**	1 19/64	**16**	1 5/16	3 3/8			12		16	
1 7/16			**12**	1 23/64	**16**	1 3/8	3 1/2	8		**12**		**16**	
1 1/2	8	1 3/8	**12**	1 27/64	**16**	1 7/16	3 5/8			12		16	
1 9/16					16	1 1/2	3 3/4	8		**12**		**16**	
1 5/8	8	1 1/2	12	1 35/64	16	1 9/16	3 7/8			12		16	
1 11/16					16	1 5/8	4	8		**12**		**16**	
1 3/4	8	1 5/8	**12**	1 43/64	**16**	1 11/16	4 1/4	8		**12**		**16**	
1 13/16					.6	1 3/4	4 1/2	8		**12**		**16**	
1 7/8	8	1 3/4	12	1 51/64	16	1 13/16	4 3/4	8		**12**		**16**	
1 15/16					16	1 7/8	5	8		**12**		**16**	
2	8	1 7/8	**12**	1 59/64	**16**	1 15/16	5 1/4	8		**12**		**16**	

[1] ASA B1.1-1949. Boldface type indicates Unified threads. Classes 2A, 2B, 2, and 3.
[2] For approximate 75% full depth of thread.

APPENDIX 9

TWIST DRILL SIZES

Size	Drill Diameter	Size	Drill Diameter	Size	Drill Diameter	Size	Drill Diameter	Size	Drill Diameter
1	.2280	17	.1730	33	.1130	49	.0730	65	.0350
2	.2210	18	.1695	34	.1110	50	.0700	66	.0330
3	.2130	19	.1660	35	.1100	51	.0670	67	.0320
4	.2090	20	.1610	36	.1065	52	.0635	68	.0310
5	.2055	21	.1590	37	.1040	53	.0595	69	.0292
6	.2040	22	.1570	38	.1015	54	.0550	70	.0280
7	.2010	23	.1540	39	.0995	55	.0520	71	.0260
8	.1990	24	.1520	40	.0980	56	.0465	72	.0250
9	.1960	25	.1495	41	.0960	57	.0430	73	.0240
10	.1935	26	.1470	42	.0935	58	.0420	74	.0225
11	.1910	27	.1440	43	.0890	59	.0410	75	.0210
12	.1890	28	.1405	44	.0860	60	.0400	76	.0200
13	.1850	29	.1360	45	.0820	61	.0390	77	.0180
14	.1820	30	.1285	46	.0810	62	.0380	78	.0160
15	.1800	31	.1200	47	.0785	63	.0370	79	.0145
16	.1770	32	.1160	48	.0760	64	.0360	80	.0135

LETTER SIZES

A	.234	G	.261	L	.290	Q	.332	V	.377
B	.238	H	.266	M	.295	R	.339	W	.386
C	.242	I	.272	N	.302	S	.348	X	.397
D	.246	J	.277	O	.316	T	.358	Y	.404
E	.250	K	.281	P	.323	U	.368	Z	.413
F	.257								

All dimensions are in inches.

Drills designated in common fractions are available in diameters 1/64" to 1¾" in 1/64" increments, 1¾" to 2¼" in 1/32" increments, and 2¼" to 3½" in 1/16" increments. Drills larger than 3½" are seldom used, and are regarded as special drills.

APPENDIX 10

AMERICAN STANDARD SQUARE AND HEXAGON BOLTS AND NUTS AND HEXAGON HEAD CAP SCREWS[1]

Nominal Size D Body Dia. of Bolt	Regular Bolts					Fin. Hex. Bolts & Hex. Cap Screws[2]		Heavy Bolts		
	Width across Flats W		Height H			Width across Flats W	Height H	Width across Flats W	Height H	
	Sq.	Hex.	Unfin. Sq.	Unfin. Hex.	Semifin. Hex.				Unfin. Hex.	Semifin. & Fin. Hex.
1/4	3/8	7/16	11/64	11/64	5/32	**7/16**	**5/32**	.....	.....	.....
5/16	1/2	1/2	13/64	7/32	13/64	**1/2**	**13/64**	.....	.....	.....
3/8	9/16	9/16	1/4	1/4	15/64	**9/16**	**15/64**	.....	.....	.....
7/16	5/8	5/8	19/64	19/64	9/32	**5/8**	**9/32**	.....	.....	.....
1/2	3/4	3/4	21/64	11/32	5/16	**3/4**	**5/16**	**7/8**	**7/16**	**13/32**
9/16	.....	.....	.....	.....	.....	**13/16**	**23/64**	.....	.....	.....
5/8	15/16	15/16	27/64	27/64	25/64	**15/16**	**25/64**	**1 1/16**	**17/32**	**1/2**
3/4	1 1/8	1 1/8	1/2	1/2	15/32	**1 1/8**	**15/32**	**1 1/4**	**5/8**	**19/32**
7/8	1 5/16	1 5/16	19/32	37/64	35/64	**1 5/16**	**35/64**	**1 7/16**	**23/32**	**11/16**
1	1 1/2	1 1/2	21/32	43/64	39/64	**1 1/2**	**39/64**	**1 5/8**	**13/16**	**3/4**
1 1/8	1 11/16	1 11/16	3/4	3/4	11/16	1 11/16	11/16	**1 13/16**	**29/32**	**27/32**
1 1/4	1 7/8	1 7/8	27/32	27/32	25/32	1 7/8	25/32	**2**	**1**	**15/16**
1 3/8	2 1/16	2 1/16	29/32	29/32	27/32	2 1/16	27/32	**2 3/16**	**1 3/32**	**1 1/32**
1 1/2	2 1/4	2 1/4	1	1	15/16	2 1/4	15/16	**2 3/8**	**1 3/16**	**1 1/8**
1 5/8	2 7/16	.....	1 3/32	.....	.....	.....	.....	2 9/16†	1 9/32†	.....
1 3/4	.....	2 5/8	.....	1 5/32	1 3/32	2 5/8	1 3/32	**2 3/4**	**1 3/8**	**1 5/16**
1 7/8	.....	.....	.....	.....	.....	.....	.....	2 15/16†	1 15/32†	.....
2	.....	3	.....	1 11/32	1 7/32	3	1 7/32	**3 1/8**	**1 9/16**	**1 7/16**
2 1/4	.....	3 3/8	.....	1 1/2	1 3/8	3 3/8	1 3/8	3 1/2	1 3/4	1 5/8
2 1/2	.....	3 3/4	.....	1 21/32	1 17/32	3 3/4	1 17/32	3 7/8	1 15/16	1 13/16
2 3/4	.....	4 1/8	.....	1 13/16	1 11/16	4 1/8	1 11/16	4 1/4	2 1/8	2
3	.....	4 1/2	.....	2	1 7/8	4 1/2	1 7/8	4 5/8	2 5/16	2 3/16
3 1/4	.....	4 7/8	.....	2 3/16	2	.....	.....	.....	.....	.....
3 1/2	.....	5 1/4	.....	2 5/16	2 1/8	.....	.....	.....	.....	.....
3 3/4	.....	5 5/8	.....	2 1/2	2 5/16	.....	.....	.....	.....	.....
4	.....	6	.....	2 11/16	2 1/2	.....	.....	.....	.....	.....

Bold face type indicates unified product.

[1] ASA B18.2–1955. All dimensions are given in inches. For thread series, minimum thread lengths, and bolt lengths, see page 375.

[2] ASA B18.6.2–1956. Hexagon head cap screw sizes 1/4 to 1 1/2 only.

†Heavy hexagon only.

APPENDIX 10

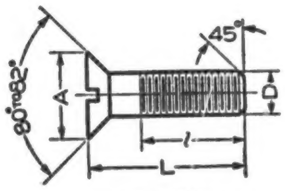
AMERICAN STANDARD SQUARE AND HEXAGON HEAD BOLTS AND NUTS AND HEXAGON HEAD CAP SCREWS (Continued)

REGULAR NUTS					FIN. HEX. NUTS		HEAVY NUTS		
Width across Flats W		Thickness T			Width across Flats W	Thick-ness T	Width across Flats W	Thickness T	
Sq.	Hex.	Unfin. Sq.	Unfin. Hex.	Semifin. Hex.				Unfin. Sq. & Hex.	Semifin. Hex.
7/16	7/16	7/32	7/32	13/64	7/16	7/32	1/2	1/4	15/64
9/16	9/16	17/64	17/64	1/4	1/2	17/64	9/16	5/16	19/64
5/8	5/8	21/64	21/64	5/16	9/16	21/64	11/16	3/8	23/64
3/4	3/4	3/8	3/8	23/64	11/16	3/8	3/4	7/16	27/64
13/16	13/16	7/16	7/16	27/64	3/4	7/16	7/8	1/2	31/64
....	7/8	....	1/2	31/64	7/8	31/64	15/16*	....	35/64
1	1	35/64	35/64	17/32	15/16	35/64	1 1/16	5/8	39/64
1 1/8	1 1/8	21/32	21/32	41/64	1 1/8	41/64	1 1/4	3/4	47/64
1 5/16	1 5/16	49/64	49/64	3/4	1 5/16	3/4	1 7/16	7/8	55/64
1 1/2	1 1/2	7/8	7/8	55/64	1 1/2	55/64	1 5/8	1	63/64
1 11/16	1 11/16	1	1	31/32	1 11/16	31/32	1 13/16	1 1/8	1 7/64
1 7/8	1 7/8	1 3/32	1 3/32	1 1/16	1 7/8	1 1/16	2	1 1/4	1 7/32
2 1/16	2 1/16	1 13/64	1 13/64	1 11/64	2 1/16	1 11/64	2 3/16	1 3/8	1 11/32
2 1/4	2 1/4	1 5/16	1 5/16	1 9/32	2 1/4	1 9/32	2 3/8	1 1/2	1 15/32
....	2 7/16*	....	....	1 25/64	.....	.....	2 9/16*	1 5/8*	1 19/32
....	2 5/8*	....	....	1 1/2	2 5/8	1 1/2	2 3/4	1 3/4	1 23/32
....	2 13/16*	....	....	1 39/64	.....	.....	2 15/16*	1 7/8*	1 27/32
....	3*	....	....	1 23/32	3	1 23/32	3 1/8	2	1 31/32
....	3 3/8*	....	....	1 59/64	3 3/8	1 59/64	3 1/2	2 1/4	2 13/64
....	3 3/4*	....	....	2 9/64	3 3/4	2 9/64	3 7/8	2 1/2	2 29/64
....	4 1/8*	....	....	2 23/64	4 1/8	2 23/64	4 1/4	2 3/4	2 45/64
....	4 1/2*	....	....	2 37/64	4 1/2	2 37/64	4 5/8	3	2 61/64
....	.....	....	....	....	.....	.....	5	3 1/4	3 3/16
....	.....	....	....	....	.....	.....	5 3/8	3 1/2	3 7/16
....	.....	....	....	....	.....	.....	5 3/4	3 3/4	3 11/16
....	.....	....	....	....	.....	.....	6 1/8	4	3 15/16

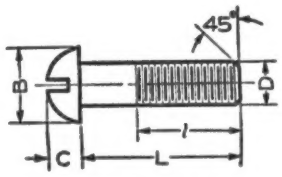
*Semifinished hexagon only. See ASA B18.2–1955 for jam nuts, slotted nuts, thick nuts, thick slotted nuts, castle nuts, and stove bolt nuts.

APPENDIX II

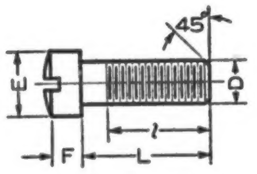
AMERICAN STANDARD SLOTTED[1] AND SOCKET HEAD[2] CAP SCREWS[3]



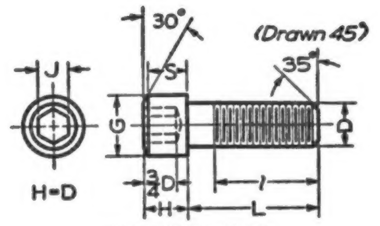
FLAT HEAD



ROUND HEAD



FILLISTER HEAD



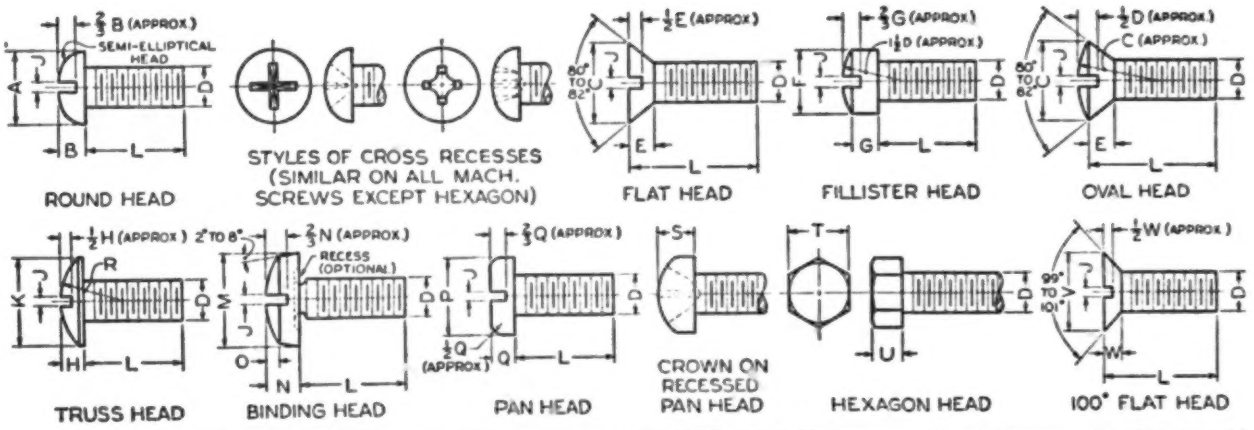
SOCKET HEAD

Nominal Size D	Flat Head[1]	Round Head[1]		Fillister Head[1]		Socket Head[2]		
	A	B	C	E	F	G	J	S
0	....	....	....	....	....	.096	.05	.055
1	....	....	....	....	....	.118	.05	.067
2 (.086)	....	....	....	....	....	.140	1/16	.079
3 (.099)	....	....	....	....	....	.161	5/64	.091
4 (.112)	....	....	....	....	....	.183	5/64	.103
5 (.125)	....	....	....	....	....	.205	3/32	.115
6 (.138)	....	....	....	....	....	.226	3/32	.127
8 (.164)	....	....	....	....	....	.270	1/8	.150
10 (.190)	....	....	....	....	....	5/16	5/32	.174
12 (.216)	....	....	....	....	....	11/32	5/32	.198
1/4	1/2	7/16	.191	3/8	11/64	3/8	3/16	.229
5/16	5/8	9/16	.245	7/16	13/64	7/16	7/32	.286
3/8	3/4	5/8	.273	9/16	1/4	9/16	5/16	.344
7/16	13/16	3/4	21/64	5/8	19/64	5/8	5/16	.401
1/2	7/8	13/16	.355	3/4	21/64	3/4	3/8	.458
9/16	1	15/16	.409	13/16	3/8	13/16	3/8	.516
5/8	1 1/8	1	7/16	7/8	27/64	7/8	1/2	.573
3/4	1 3/8	1 1/4	35/64	1	1/2	1	9/16	.688
7/8	1 5/8	....	....	1 1/8	19/32	1 1/8	9/16	.802
1	1 7/8	....	....	1 5/16	21/32	1 5/16	5/8	.917
1 1/8	2 1/16	....	....	....	....	1 1/2	3/4	1.031
1 1/4	2 5/16	....	....	....	....	1 3/4	3/4	1.146
1 3/8	2 9/16	....	....	....	....	1 7/8	3/4	1.260
1 1/2	2 13/16	....	....	....	....	2	1	1.375

[1] ASA B18.6.2-1956. [2] ASA B18.3-1954. [3] See Hexagon Head Screws

APPENDIX 12

AMERICAN STANDARD MACHINE SCREWS[1]


⅔ B (APPROX.)
SEMI-ELLIPTICAL HEAD
A
J
D
B
L
ROUND HEAD
STYLES OF CROSS RECESSES (SIMILAR ON ALL MACH. SCREWS EXCEPT HEXAGON)
½ E (APPROX.)
80° TO 82°
C
J
D
E
L
FLAT HEAD
⅔ G (APPROX.)
1½ D (APPROX.)
F
J
D
G
L
FILLISTER HEAD
½ D (APPROX.)
C (APPROX.)
80° TO 82°
C
J
D
E
L
OVAL HEAD
½ H (APPROX.)
R
K
J
D
H
L
TRUSS HEAD
2° TO 8°
⅔ N (APPROX.)
RECESS (OPTIONAL)
M
J
D
O
N
L
BINDING HEAD
⅔ Q (APPROX.)
P
J
D
½ Q (APPROX.)
Q
L
PAN HEAD
S
CROWN ON RECESSED PAN HEAD
T
U
D
HEXAGON HEAD
½ W (APPROX.)
99° TO 101°
V
J
D
W
L
100° FLAT HEAD

Nom. Size	Max. Diam. D	Round Head		Flat Heads & Oval Head		Fillister Head		Truss Head			Width of Slots
		A	B	C	E	F	G	K	H	R	
0	0.060	0.113	0.053	0.119	0.035	0.096	0.045	....	....	....	0.023
1	0.073	0.138	0.061	0.146	0.043	0.118	0.053	....	....	....	0.026
2	0.086	0.162	0.069	0.172	0.051	0.140	0.062	0.194	0.053	0.129	0.031
3	0.099	0.187	0.078	0.199	0.059	0.161	0.070	0.226	0.061	0.151	0.035
4	0.112	0.211	0.086	0.225	0.067	0.183	0.079	0.257	0.069	0.169	0.039
5	0.125	0.236	0.095	0.252	0.075	0.205	0.088	0.289	0.078	0.191	0.043
6	0.138	0.260	0.103	0.279	0.083	0.226	0.096	0.321	0.086	0.211	0.048
8	0.164	0.309	0.120	0.332	0.100	0.270	0.113	0.384	0.102	0.254	0.054
10	0.190	0.359	0.137	0.385	0.116	0.313	0.130	0.448	0.118	0.283	0.060
12	0.216	0.408	0.153	0.438	0.132	0.357	0.148	0.511	0.134	0.336	0.067
¼	0.250	0.472	0.175	0.507	0.153	0.414	0.170	0.573	0.150	0.375	0.075
5⁄16	0.3125	0.590	0.216	0.635	0.191	0.518	0.211	0.698	0.183	0.457	0.084
⅜	0.375	0.708	0.256	0.762	0.230	0.622	0.253	0.823	0.215	0.538	0.094
7⁄16	0.4375	0.750	0.328	0.812	0.223	0.625	0.265	0.948	0.248	0.619	0.094
½	0.500	0.813	0.355	0.875	0.223	0.750	0.297	1.073	0.280	0.701	0.106
9⁄16	0.5625	0.938	0.410	1.000	0.260	0.812	0.336	1.198	0.312	0.783	0.118
⅝	0.625	1.000	0.438	1.125	0.298	0.875	0.375	1.323	0.345	0.863	0.133
¾	0.750	1.250	0.547	1.375	0.372	1.000	0.441	1.573	0.410	1.024	0.149

Nom. Size	Max. Diam. D	Binding Head			Pan Head			Hexagon Head		100° Flat Head		Width of Slots
		M	N	O	P	Q	S	T	U	V	W	
2	0.086	0.181	0.046	0.018	0.167	0.053	0.062	0.125	0.050	....	....	0.031
3	0.099	0.208	0.054	0.022	0.193	0.060	0.071	0.187	0.055	....	....	0.035
4	0.112	0.235	0.063	0.025	0.219	0.068	0.080	0.187	0.060	0.225	0.048	0.039
5	0.125	0.263	0.071	0.029	0.245	0.075	0.089	0.187	0.070	....	....	0.043
6	0.138	0.290	0.080	0.032	0.270	0.082	0.097	0.250	0.080	0.279	0.060	0.048
8	0.164	0.344	0.097	0.039	0.322	0.096	0.115	0.250	0.110	0.332	0.072	0.054
10	0.190	0.399	0.114	0.045	0.373	0.110	0.133	0.312	0.120	0.385	0.083	0.060
12	0.216	0.454	0.130	0.052	0.425	0.125	0.151	0.312	0.155	....	....	0.067
¼	0.250	0.513	0.153	0.061	0.492	0.144	0.175	0.375	0.190	0.507	0.110	0.075
5⁄16	0.3125	0.641	0.193	0.077	0.615	0.178	0.218	0.500	0.230	0.635	0.138	0.084
⅜	0.375	0.769	0.234	0.094	0.740	0.212	0.261	0.562	0.295	0.762	0.165	0.094

[1] ASA B18.6–1947.

Length of Thread: On screws 2″ long and shorter, the threads extend to within two threads of the head and closer if practicable; longer screws have minimum thread length of 1¾″.

Points: Machine screws are regularly made with plain sheared ends, not chamfered.

Threads: Either Coarse or Fine Thread Series, Class 2 fit.

Recessed Heads: Two styles of cross recesses are available on all screws except hexagon head.

END 9·2·69